1-1-1988

Virginia Institute of Marine Science Forty-Sixth Annual Report

Virginia Institute of Marine Science

Forty-Sixth

ANNUAL REPORT

Virginia Institute of Marine Science
School of Marine Science
The College of William and Mary

1987

On the Cover
The 65-foot Research Vessel Bay Eagle joined the Institute's research fleet in February of 1987.

Forty-Sixth

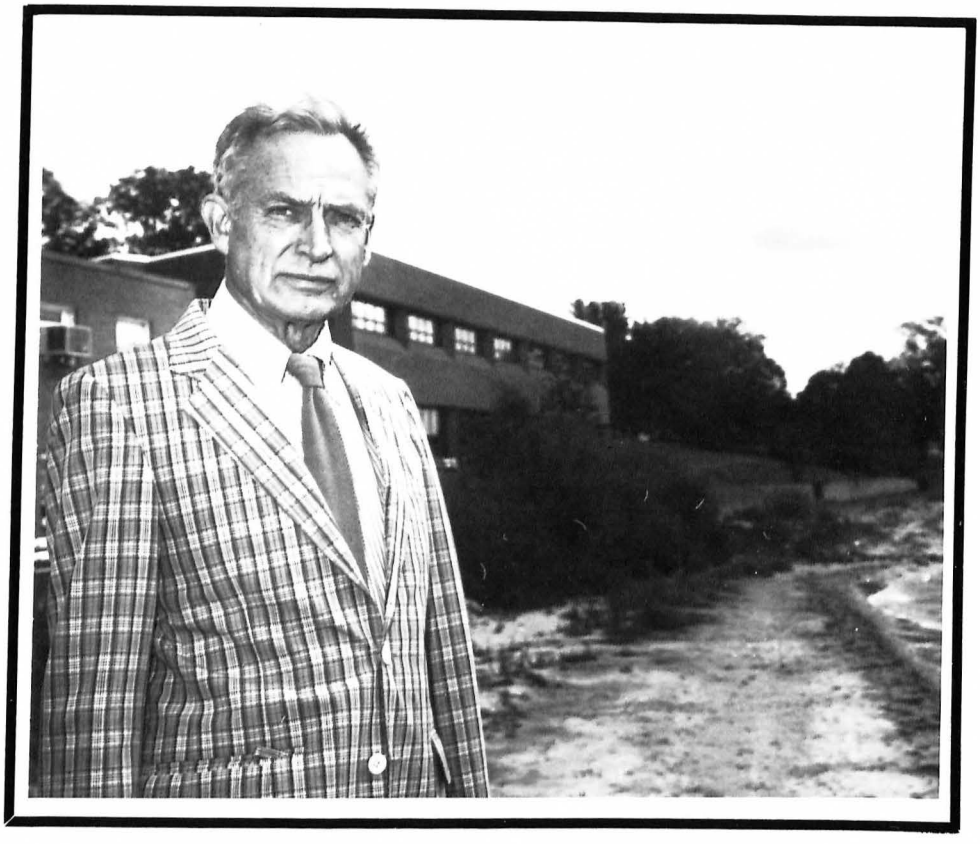
ANNUAL REPORT

for the period ending June 30, 1987

Virginia Institute of Marine Science
School of Marine Science
The College of William and Mary
Gloucester Point, Virginia 23062

VIMS

IN TRIBUTE . . .



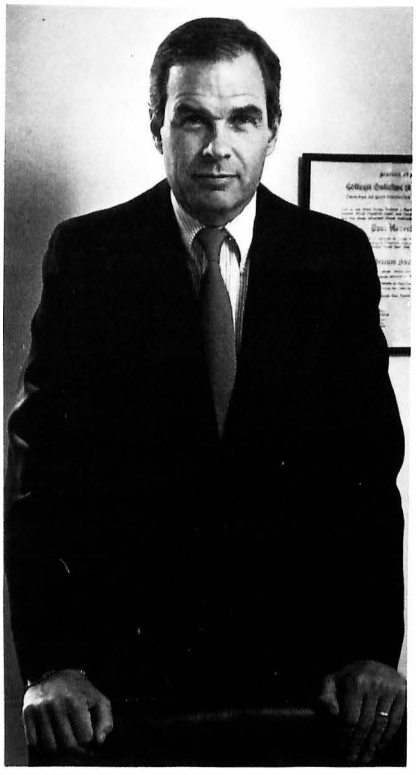
John Milton Zeigler *joined the staff of VIMS in 1971. He will be remembered in ways large and small: the Zeiglerama dances, advice on gardening, a scintillating party at the Zeigler house, help with the history of England or the Civil War period, help in coping with the anxieties of being a graduate student or a member of the faculty. Some were lucky enough to spend time on a beach with John--that land-sea form was his favorite. John brought all these facets to us, and much, much more. His death on January 2, 1987, was felt throughout the College family.*

A geologist with broad interests (Harvard Ph.D., 1954), John was above all a classical geomorphologist fascinated with the prospect of incorporating physics to explain land forms, including those beneath the sea. After 14 fruitful years at the Woods Hole Oceanographic Institution investigating both deep sea and coastal sedimentation processes, he took up a post as Professor of Marine Geology at the University of Puerto Rico. The Caribbean was an area of long and lasting interest until his death.

As Assistant Director, Division of Physical and Engineering Sciences, John's leadership resulted in the expansion of those programs and the opening of new areas of interest and expertise at VIMS. However, his influence was much more pervasive. He was the shepherd of the Bylaws of the Faculty of the School of Marine Science. He ministered to the graduate students, regardless of their disciplines. Finally, John enjoyed the challenge of communicating the results of scientific inquiry to resource managers. In 1980 John became the first Associate Director for Research and Education. In this post he provided singular attributes to meet the needs of the students and faculty. The keystone of John's philosophy was that the pursuits of rational science and the education of students were marvelous human endeavors. His goal was to help others enjoy the excitement of rigorous inquiry, and he communicated that to faculty, students and staff. It is fitting to note that the General Assembly of the Commonwealth of Virginia, by House Joint Resolution #344, 1987, acknowledged the particular contributions of John M. Zeigler.

The students, staff and faculty of the Virginia Institute of Marine Science/School of Marine Science of the College of William and Mary take this opportunity to acknowledge, with deep gratitude, Professor Zeigler's contribution to the College of William and Mary and to the Commonwealth of Virginia.

Table of Contents



The Honorable Gerald L. Baliles
Governor of Virginia
State Capitol
Richmond, Virginia 23219

Dear Governor Baliles:

It is my pleasure to submit this forty-sixth Annual Report of the Virginia Institute of Marine Science/School of Marine Science, College of William and Mary, covering the year ending June 30, 1987.

Throughout the year, VIMS has continued its dedication to excellence in education, research, and public service activities, focusing on studies and programs designed to improve understanding of the Chesapeake Bay system and the Commonwealth's other estuarine and coastal environments.

One significant and gratifying outcome of our research and advisory efforts was the enactment by the General Assembly of legislation to restrict the usage of the toxic chemical compound tributyltin (TBT). As you know, this legislation is already serving as a legislative model for other states and the U.S. Congress.

We have made substantial gains in research on immunology, sediment dynamics and plankton ecology, and are exploring new interdisciplinary approaches to the complex problems of toxic wastes.

VIMS' Advisory Services Department again served as host for the NASA/VIMS Governor's School, a special summer program in education for gifted and talented high school students.

Finally, the Institute has carried out an administrative restructuring designed to reduce the number of scientists in administration and provide better support for the academic and research programs.

Sincerely,

Paul R. Verkuil

Paul R. Verkuil
President

THE COLLEGE OF WILLIAM AND MARY
BOARD OF VISITORS

Hays T. Watkins ..... Rector
Henry T. Tucker, Jr. ..... Vice Rector
Harriet N. Storm ..... Secretary

James W. Brinkley
Edward J. Campbell
Sharon A. Coles-Stewart
The Honorable Richard J. Davis
Stewart H. Gamage
Lewis L. Glucksman
Pamela C. Harriman
Audrey M. Harris
The Honorable A. Linwood Holton
Carlisle H. Humelsine
Joseph R. Koons
James W. McGlothlin
John H. Tucker, Jr.
James E. Ukrop

OFFICERS OF ADMINISTRATION

Paul R. Verkuil ..... President
Melvyn D. Schiavelli ..... Provost
William F. Merck, II ..... Vice President for Administration and Finance
Edward T. Allenby ..... Vice President for University Advancement

VIRGINIA INSTITUTE OF MARINE SCIENCE
SCHOOL OF MARINE SCIENCE
ADMINISTRATION

Frank O. Perkins ..... Director and Dean
Maurice P. Lynch ..... Associate Dean
Robert J. Byrne ..... Associate Director for Research
Paul V. Koehly ..... Associate Director for Finance and Administration
Michael Castagna ..... Assistant Director and Scientist-in-Charge of Eastern Shore Laboratory
Robert J. Huggett ..... Assistant Director for Division of Chemistry and Toxicology
Robert J. Orth ..... Assistant Director for Division of Biological and Fisheries Sciences
L. Donelson Wright ..... Assistant Director for Division of Geological and Benthic Oceanography
Bruce J. Neilson ..... Assistant Director for Division of Physical Oceanography and Environmental Engineering

MARINE SCIENCE DEVELOPMENT COUNCIL

The Marine Science Development Council is an advisory body composed of leaders from Virginia's business and industrial communities who are interested in the continuing vitality of VIMS and its role in advising managers of Virginia's marine and estuarine natural resources. The primary function of the Council is to advise the Dean/Director of the Institute on planning and implementation of research and advisory services programs as they relate to the private sector.

Additionally, the Council advises the Institute on its private sector initiative program. This program is directed toward assisting VIMS in securing private resources to accomplish its goals.

The membership of the Marine Science Development Council includes the following persons:

Mr. George W. Roper, II, Council Chairman
Norfolk Shipbuilding and Drydock Corporation
Norfolk, Virginia

Dr. Wallace W. Atwood, Jr.
Former Director
Office of International Relations
National Academy of Sciences
White Stone, Virginia

Mr. C. C. Ballard
Ballard Fish & Oyster Company, Inc.
Norfolk, Virginia

Mr. Fred M. Biddlecomb
Virginia Waterman's Association
Reedville, Virginia

Mr. Samuel C. Brown, Jr.
Senior Vice President
Corporate Technical Assessment
Virginia Electric and Power Company
Richmond, Virginia

Mr. Louis N. Dibrell, Jr.
Former Executive Vice President
Dibrell Brothers, Incorporated
Danville, Virginia

Mr. Frederick V. Ernst
Group Vice President- Pulp and Paper
Chesapeake Corporation
West Point, Virginia

Mr. Bruce C. Gottwald
President
Ethyl Corporation
Richmond, Virginia

Mr. Emory A. Gross
President
Fire Suppression Systems
Virginia Beach, Virginia

Vice Admiral Vincent A. Lascara
U.S.N. (Ret.)
Vice President
The Jonathan Corporation
Norfolk, Virginia

Mr. E. Morgan Massey, President
A. T. Massey Coal Company, Inc.
Richmond, Virginia

Mr. John R. Miles, President
J. H. Miles & Company, Inc.
Norfolk, Virginia

Mr. William C. Monroe, A.I.A.
Caro, Monroe, Liang- Architects
Newport News, Virginia

Mr. Joseph R. Neikirk, Vice President
Personnel and Labor Relations
Norfolk Southern Corporation
Norfolk, Virginia

Mr. F. Farrell Sanders, Director
Technical Services
Newport News Shipbuilding
and Drydock Company
Newport News, Virginia

Mr. Samuel Sandler
Chairman of the Board
Sandler Foods
Virginia Beach, Virginia

Mr. Guilford D. Ware
Creshaw, Ware & Johnson
Norfolk, Virginia

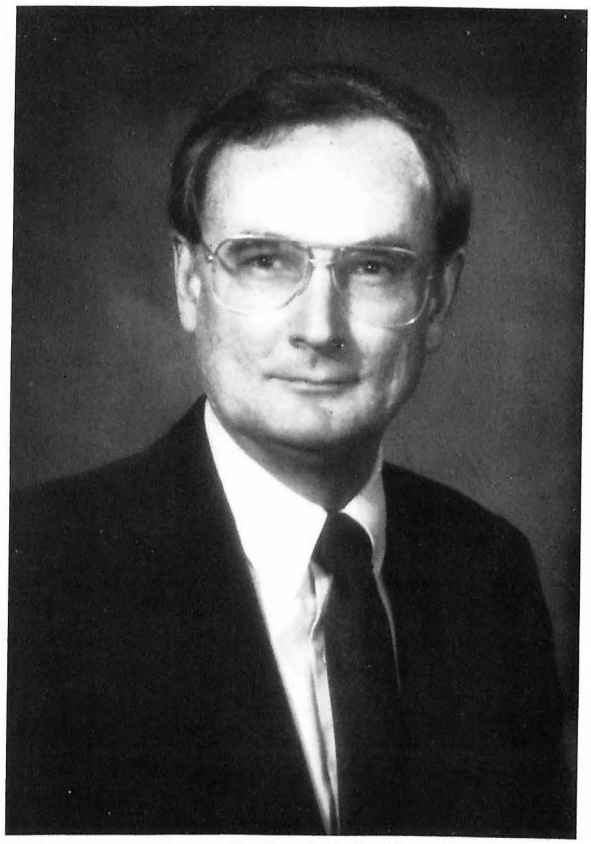
Captain J. Maury Werth, U.S.N. (Ret.)
Former Superintendent of the
U.S. Navy Observatory
Hagerstown, Maryland

Mr. Scott C. Whitney, Professor of Law
George Mason University and
Director, Institute of Law and Public
Health Protection
Arlington, Virginia

Mr. George A. Zahn, Jr.
Consulting Engineer
Gloucester, Virginia


N2

Highlights of 1986-1987



Dr. Frank O. Perkins, Dean/Director

Established by the Commonwealth in 1940 as the Virginia Fisheries Laboratory, the Virginia Institute of Marine Science has expanded to become an internationally-recognized research and service institution in the field of marine science.

Dedicated to excellence in education, research, and public service for the people of Virginia and the broader scientific community, VIMS has its principal campus just across the York River from Yorktown. This location on an important estuary with easy access to the Chesapeake Bay and the nearby Atlantic Ocean provides VIMS with an ideal base for performing its teaching and research activities. A second, smaller campus at Wachapreague houses the Eastern Shore Laboratory and is strategically situated for work on the embayments, salt marshes, barrier beaches, and coastal waters of the Eastern Shore.

The Institute has a faculty of 68 full-time members, supported by a comprehensive library and a modern computer center. Under the aegis of the College of William and Mary, School of Marine Science, VIMS offers the graduate degrees of Master of Arts and Doctor of Philosophy in Marine Science, and has a current enrollment of 110 students from several states and foreign countries.

Education

A total of twenty-three degrees were awarded in Marine Science, making the class of 1986-1987 the largest in the past five years. Ten individuals received the Doctor of Philosophy degree, and thirteen the Masters degree.

- Anne Frazier Markwith, the first student with a combined education-marine science degree, graduated this past year, marking the advancement of a cooperative plan between VIMS and the School of Education at William and Mary to help improve awareness of science in the elementary and secondary schools of the Commonwealth. This new graduate program offers a Master of Arts in Education in Secondary School Teaching with an emphasis in Marine Science.
- A new annual award was established to recognize outstanding teaching and research by VIMS faculty, and the first recipient of the outstanding teaching award was Dr. Evon P. Ruzecki, Associate Professor, a member of the Physical Oceanography subfaculty.

Mr. William Nuckols, a 1987 Virginia Environmental Endowment Summer Research Aide, examines a water sample as part of his work in phosphorus research.

- A special endowment to honor the late Dr. John M. Zeigler, Associate Dean, was created to support an annual Outstanding Student Achievement Award. The first award will be presented next year.

Research

Important gains were made in many of the fifteen program areas, with substantial progress in plankton ecology, immunology, and sediment dynamics.

- Since 1985, members of the VIMS faculty have made important progress in state-of-the-art techniques for studying the smallest members of the plankton community. Using color video image analysis with fluorescence microscopy this community of bacteria, phytoplankton and microzooplankton can be rapidly characterized. These advances may lead to new means of measuring the overall health of estuarine systems.
- Advances were also made during the year in developing and applying procedures to test the condition of the immune systems of finfish. Earlier VIMS studies have shown that toxic organic chemicals can dramatically suppress the immune systems of finfish, and continuing research indicates that there could be application of biomedical techniques to measure the health of estuarine systems at the organismic level, helping to trace the impacts and sources of toxic influences before the problems spread.
- The development of new instrument systems helped improve understanding of the transport and deposition of fine-grained sediments and how these movements relate to the transport of toxic chemicals.
- Research into oyster diseases documented that a second year of severe drought and high salinities contributed to epidemics caused by two major oyster diseases, MSX (*Haplosporidium nelsoni*) and Dermo (*Perkinsus marinus*), in the Bay and major tributaries.
- Results of continuing research indicate that oysters are able to accumulate and conserve omega-3 fatty acids in their neutral and polar lipids for long periods, suggesting that there may be health advantages to including oysters regularly in a diet.
- Studies at VIMS and other institutions suggest that the fecal coliform indicator used to classify shellfish growing areas is an inadequate indicator of public health risk, and VIMS microbiologists continue to search for improved or alternate methods to measure this risk.
- Acting on VIMS studies and recommendations, the Virginia Marine Resources Commission and the Virginia Department of Health have developed regulations permitting containerized relaying of hard clams, a process which provides significant economic advantages.
- Studies of the effects of tributyltin (TBT) suggest that using the chemiluminescence immunological assay has potential value in measuring overall fish health and the biological effects of exposure to toxicants.
- While progressing with the location and mapping of subaqueous mineral resources of the Commonwealth, VIMS researchers located significant new fossil shell reserves in at least two locations within the lower Chesapeake Bay.
- Techniques for mass production of eyed larvae in the oyster hatchery were improved, permitting routine yields at the level of 300 million larvae per year.

Advisory Services

- Cumulative research by VIMS faculty and students on the toxicity of the antifouling paint additive TBT, contributed substantially to the decision this year by the General Assembly to enact landmark legislation to restrict usage of TBT, and these changes in Virginia law are now serving as a model for many states and the U.S. Congress.
- VIMS' Advisory Services again served as host for the Virginia NASA/VIMS Governor's School, a six-week summer program of education in marine science for gifted and talented high school students, sponsored by the Virginia Department of Education.

- The oyster hatchery outreach program has expanded substantially. In 1986-1987 the remote setting program saw the initiation of two scale-up operations using VIMS larvae. A 1,500 bushel and a 900 bushel setting program were begun in collaboration with members of the oyster industry.

Financial Management

- The Institute experienced another year of growth as reflected by cash expenditures (see Page 73) for the fiscal year. The State funded activity increased from $8.9 million in 1986 to $9.6 million in 1987 or approximately 8%. The sponsored research activity also increased during the year from $2.9 million in 1986 to $3.3 million during 1987, or approximately 13%.

Administration

- VIMS carried out an administrative restructuring during the year, with the goal of providing better support to the academic program and reducing the total number of scientists involved in administration. The new organization chart (see Page 87) results from the replacement of four research divisions and eight distinct departments with five divisions and two departments, and reflects a reduction of science-administrators from thirteen to nine. Each new division is more interdisciplinary in composition and function.


B
2000ml
KIMAX
2000ml
KIMAX

Piecing Together the Toxics Puzzle: New Approaches at VIMS

In the 380 years that have passed since Captain John Smith first explored the Chesapeake Bay and its tributaries, man has developed an ambiguous relationship with the majestic estuary. We have marveled at the diversity of the Bay's marine life, and prospered from its abundance. Generations of children have grown up with delightful memories of swimming and sailing in the Chesapeake. But, particularly in this century, we have flocked to the shorelines in increasing numbers, building homes and factories, and using the Bay as a handy disposal system for chemical and domestic wastes of every kind and magnitude.

Within the past decade, marine scientists, environmental managers and concerned political leaders have found a new unity in their accelerated efforts to counteract the steadily growing flow of toxic chemicals to the marine environment.

Toxic chemicals, in their manifest forms, remain one of the most serious threats to our oceans and estuaries, our rivers and streams, and in the end, to people. In recent years, VIMS has been making steady progress in isolating, identifying, and understanding many pieces of the complex puzzle of toxic waste. And now, scientists in the Division of Chemistry and Toxicology have embarked on a bold new approach to the toxics challenge, combining the skills and techniques of immunology, pathology and chemistry in a multidisciplinary attack on the problems.

In the past, classical approaches for measuring the biological effects of toxic pollutants have not been adequate in assessing such chronic efforts as the formation of tumors or the diminished ability of fish to fight disease. Hence, in their new pathological studies, VIMS scientists are concentrating on ways to unravel the secrets of how toxicants interact with cells, tissues and organs of aquatic animals, and to learn whether or not such effects are reversible.

For example, it has long been known that finfish exposed to chemically-inhospitable environments may develop skin growths, ulcerations, and lesions. Other glaring changes in form and structure such as emaciation, discolored or abnormally textured gills, and eye disorders have also been associated with exposure to toxicants. Scientists at VIMS have observed all of these effects in fishes exposed to the heavy burdens of sediment-associated toxicants in the Elizabeth River.

Consequently, they have proposed the use of such effects observed in both "planted" and feral or "wild" populations to establish the existence of toxic contaminants. These readily observable pathological signs will be useful in surveys to establish the geographical location and extent of pollution, and the effects will also be useful in establishing water quality criteria and standards for water quality management.

The immune system of fishes, like those of higher vertebrates, including man and laboratory animals, is sensitive to challenges by infectious agents and to other stresses including chemical contaminants. Should the immune system falter, disease appears, and if immune system fails, death ultimately results. In studies of estuarine fish, including spot, flounder, hogchoker and toadfish, VIMS scientists have found that macrophages (key cells in the immune system) extracted from fish exposed to the various complex contaminants in the Elizabeth River are less able to migrate, to chemiluminesce, and to ingest and kill bacteria than those from the cleaner York River nearby, or from other reference systems in the lower Bay.

Laboratory Specialist Donna Westbrook extracts water for tributyltin analysis.

These findings have been verified by controlled exposures of the same species to the same sediment-related toxicants in the laboratory. These immune responses are so obvious as to be repeatable and easily detected, making them especially useful in assaying for fish health and distinguishing animals in a stressed environment from those in a nonstressed one. The techniques appear to be much more sensitive than the classical chemical and histological measures of pollution effects. Further, the responses are signs provided by the fish themselves when toxic conditions prevail. Since these immune-based bioassays are quickly carried out, they could be especially useful in studies of environmental contamination and in the management of pollution.

For the past twenty years, chemists at VIMS have been applying advanced methods of chemical analysis to estuarine samples to determine the extent of pollution in the Chesapeake Bay and its tributaries. This work has uncovered the ubiquitous presence of polynuclear aromatic hydrocarbons (PAH) as major pollutants in sediments, and has identified the Elizabeth River as one of the most seriously polluted areas within the continental U.S. Also, the distribution of Kepone in the lower James River was elucidated, and the omnipresence of tributyltin (TBT) in the harbors and marinas of the Bay was documented.

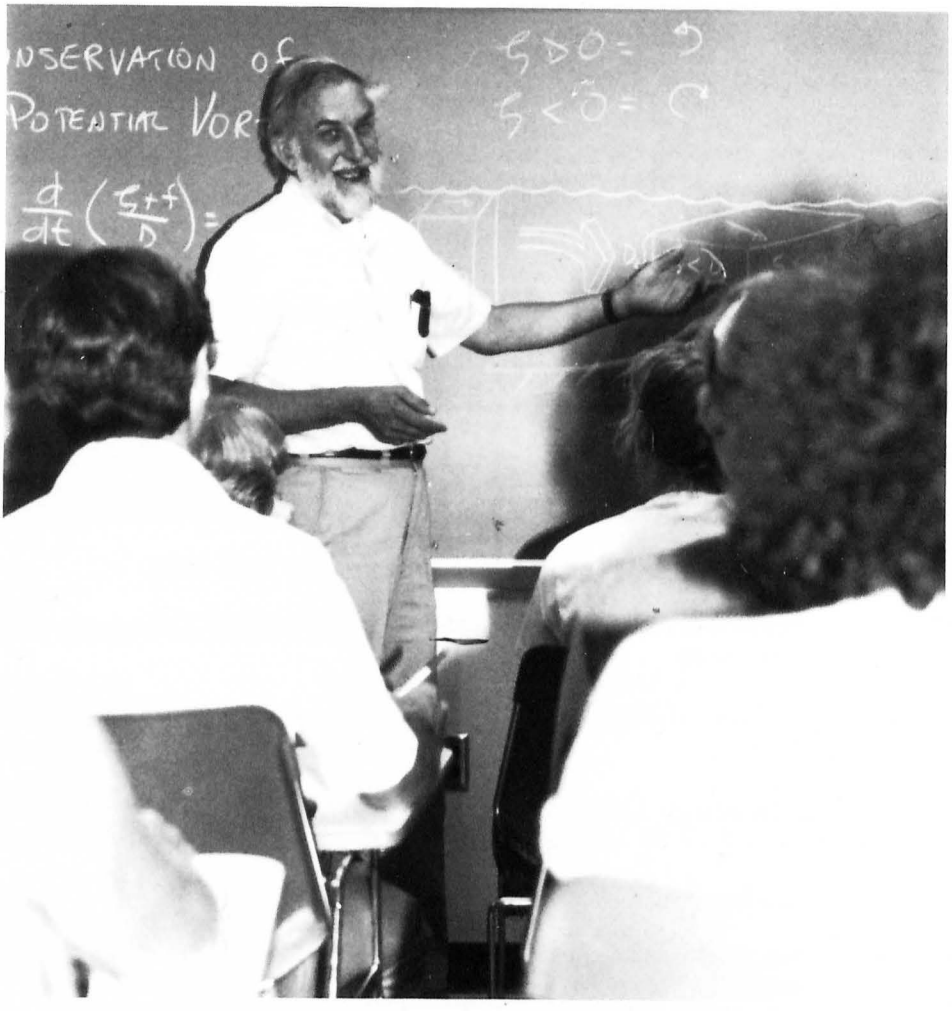
More recently, attention has been directed toward a detailed chemical assessment of various pollutants in estuarine plant and animal life. For instance, when PAH are metabolized by finfish, some of the byproducts formed become powerful mutagens and/or carcinogens. These metabolites, especially those that are conjugated, are much more difficult to characterize than their parent compounds. They tend to be nonvolatile, water soluble and temperature sensitive, properties which make the analysis of such compounds difficult and demand the use of the most advanced methodologies available.By utilizing high performance liquid chromatography-mass spectrometry, scientists at VIMS have been able to characterize several metabolites of benzo(a)pyrene, a PAH that is known to be changed to a very powerful carcinogen by some marine organisms. Although the transition from the relatively simple analysis of pollutants to the inclusion of metabolites is substantial, it is only a beginning.

Considering the incredible complexity of biological systems and the diversity of chemicals being released into the aquatic environment and the multiplicity of metabolites they are capable of forming, there remain many facets of the problem to investigate. For example, the interaction of toxic organic materials with cellular components and molecules and the role of pollutants in the induction of immune responses must be studied carefully in order to begin understanding the disease process. An expansion of the VIMS program will include studies of other substances known to be of acute or chronic toxicity and will involve efforts to reduce detection limits from parts per billion to parts per trillion in tissues and sediments.

Most estimates indicate that by the end of the 20th century, more than 75 percent of the nation's population will be living within 50 miles of a coastline. Obviously, there will be greater demands on our coastal waters. The interdisciplinary approaches by VIMS, drawing upon the vast amount of knowledge developed over the last century in medical and veterinary research centers, and applying it to aquatic systems, can play a vital role in preserving the majestic Chesapeake Bay and its irreplaceable plants and animals.

Division of Chemistry and Toxicology principal researchers: (seated) R. Huggett, (standing left to right) J. Greaves, E. Warinner, D. Zwerner, W. Hargis, M. Roberts, M. Bender, A. Weeks and (back) R. Hale. Not pictured are R. Bieri, A. Deshpande and A. Thiyagarajah.

Graduate Education



Dr. Evon P. Ruzecki

In 1986-1987 twenty-three degrees were awarded in Marine Science. Ten individuals were awarded the Doctor of Philosophy degree and thirteen received their Master's degree. This was the School of Marine Science's largest graduating body in the last five years.

In order to provide well deserved recognition to the talents and dedication of the faculty and staff at VIMS, an annual award was established this year. The award is given in alternate years for outstanding teaching and outstanding research. Dr. Evon P. Ruzecki, Associate Professor of Marine Science, was awarded the outstanding teaching award for 1986-1987. Dr. Ruzecki is a member of the Physical Oceanography subfaculty.

An endowment was established to provide an Outstanding Student Achievement Award in honor of the late Dr. John M. Zeigler, former Associate Dean/Director for Research and Education. This award will be made during 1987-1988.

An important milestone was passed with the graduation of the first student from the School of Education/School of Marine Science--Master of Arts in Education in Secondary School Teaching with an Emphasis in Marine Science. This program was jointly developed by the Schools of Education and Marine Science in recognition of the need to bring enhanced awareness of science (particularly marine science) into the elementary and secondary schools of the Commonweath.

STATISTICAL PROFILE FOR THE ACADEMIC YEARS 1984, 1985, AND 1986

All students who registered in the fall of 1984, 1985, and 1986

Ph.D.				M.A.			
Male		Female		Male		Female	
1984	33	1984	10	1984	37	1984	30
1985	39	1985	10	1985	36	1985	34
1986	46	1986	9	1986	33	1986	26

	Students Registered	Students on Leave	Total
1984	110	16	126
1985	119	20	139
1986	114	20	134

Resident Status:	In-State	Out-of-State	Foreign
1984	61	39	10
1985	59	45	15
1986	51	41	22

Student Support for Fall 1986

Assistantships	80
Fellowships (GPOP awards and foreign scholarships)	5
Internships	0
William and Mary Teaching Assistantships	0
William and Mary Workship	2
TOTAL	87

Marine Science Degrees Awarded by the College of William and Mary for the Past Five Academic Years

Academic Year	Masters	Doctorates
1982-1983	15	5
1983-1984	6	12
1984-1985	10	9
1985-1986	5	8
1986-1987	13	10

Matriculations in the School of Marine Science for the Past Five Academic Years

Academic Year	Inquiries	Applications Completed	No. of New Students Who Matriculated
1982-1983	183	86	19
1983-1984	332	63	19
1984-1985	370	77	13
1985-1986	335	78	26
1986-1987	415	70	16

DOCTORAL DISSERTATIONS IN MARINE SCIENCE COMPLETED DURING THE 1986-1987 ACADEMIC YEAR

BERQUIST, CARL RICHARD, JR.
Stratigraphy and Heavy Metal Analysis in the Lower Chesapeake Bay, Virginia. (John D. Boon, III)*

BOYER, JOSEPH N.
Degradation and Mineralization of Chitin in an Estuary. (Howard I. Kator)

DeALTERIS, JOSEPH T.
The Sedimentary Processes and Geomorphic History of Wreck Shoal, an Oyster Reef of the James River, Virginia. (Robert J. Byrne)

FINKELSTEIN, KENNETH
The Late Quaternary Evolution of a Twin Barrier-Island Complex, Cape Charles, Virginia. (L. Donelson Wright)

FRITZ, ALYCE THOMSON
Trophodynamics of Estuarine (Salt Marsh) Heterotrophic Nanoplankton. (Kenneth L. Webb)

GUSSMAN, DAVID S.
The Use of Brewers Condensed Solubles in Bivalve Mariculture. (Howard I. Kator and Morris H. Roberts, Jr.)

HUZZEY, LINDA M.
Lateral Variability in a Coastal Plain Estuary. (John M. Brubaker)

MIDDLETON, ROBERT W.
The Seasonal and Diel Use by Juvenile and Adult Finfishes of a Mesohaline Intertidal Creek on the York River, Virginia. (Richard L. Wetzel and John A. Musick)

PRICE, JAMES E.
Estuarine Zooplankton Community Structure in Stratified and Well-Mixed Environments. (George C. Grant)

SCHAFFNER, LINDA C.
Ecology of the Benthos of the Lower Chesapeake Bay. (Robert J. Diaz)

MASTER OF ARTS THESES IN MARINE SCIENCE COMPLETED DURING THE 1986-1987 ACADEMIC YEAR

ATRAN, STEVEN M.
Fluctuations in the Catchability Coefficient of Atlantic Menhaden, 1968- 1982. (Joseph G. Loesch)

COMYNS, BRUCE H.
Identification and Distribution of *Urophycis* (Gill) and *Phycis* (Artedi) Larvae and Pelagic Juveniles in the Middle Atlantic Bight. (George C. Grant)

* Major professor(s) named in parentheses

DELANEY, GLENN ROGER
Morphometric and Meristic Stock Identification of Summer Flounder (*Paralichthys dentatus*). (John A. Musick)

De LUCA, MICHAEL P.
Recommendations for Amelioration of Legal and Environmental Concerns about Mining of Deepsea Deposits of Polymetallic Sulfides. (N. Bartlett Theberge and Carl H. Hobbs, III)

DiCOSIMO, JANE
Biological Review and Commercial Whelk Fisheries Analysis of *Busycon carica* with Comments on *B. canaliculatum* and *B. contrarium* in Virginia. (William D. DuPaul)

DUNCAN, PATRICIA L.
The Use of Crab Meal as a Supplemental Food for Juvenile Hard Clams (*Mercenaria mercenaria*). (William D. DuPaul and Michael Castagna)

FOWLER, BRYAN KEITH
Primary Production and Temporal Variation in the Macrophytic Community of a Tidal Freshwater Swamp. (Carl H. Hershner)

GAMMISCH, ROBERT A.
Geological History of a Holocene Drainage System, Hack Creek, Virginia. (Robert J. Byrne)

HUQ, MARIAN VANCE
Vegetation of Selected Dune Ridges and Marshes on the Eastern Shore of Virginia: Community Structure and Relationship to Environmental Factors. (Gene M. Silberhorn)

JANSEN, MAURA E.
Parasite Community Structure in Summer Flounder, *Paralichthys dentatus* (Linnaeus), of the Chesapeake Bay. (Eugene M. Burreson)

RAY, ROBERT TRIAU
The Role of Picoplankton in Phytoplankton Dynamics of a Temperate Coastal Plain Estuary. (Leonard W. Haas)

SMINKEY, THOMAS R.
A Morphological Study of the Pharyngeal Sac of Two Species of Stromateid Fishes, *Peprilus triacanthus* and *P. paru*. (John A. Musick)

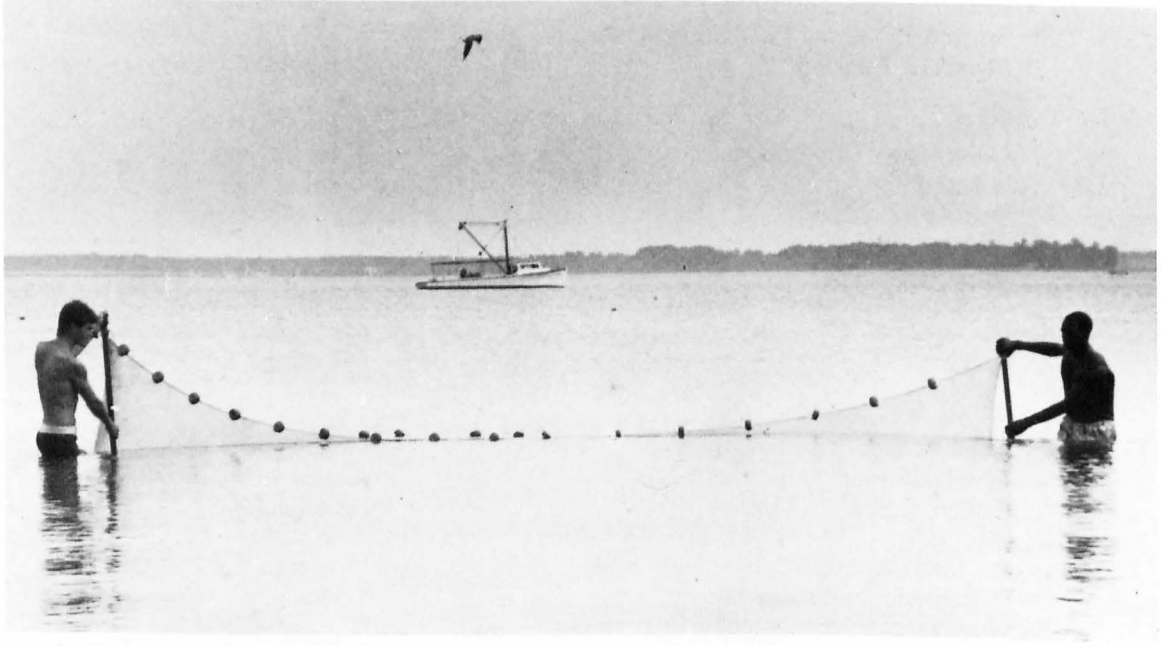
SMITH, STEPHEN M.
Reproductive Ecology, Population Dynamics and Seasonal Movements of the Hogchoker (*Trinectes maculatus*), in the Elizabeth River, Virginia. (John A. Musick).

Summer Intern Program

The summer of 1987 marked the beginning of the third year of the VIMS summer program for minority undergraduates who might be considering a career in Marine Science. Funding for four interns was provided by the Exxon Foundation. In addition one intern was supported by the U.S. Department of Education cooperative Minority Institutions Improvement Program (MISIP) between Hampton University and the School of Marine Science.

Summer Interns at VIMS 1986 and 1987

Name	Supported by	Home University
	1986	
Scott Gregg	Exxon	University of Maryland, Eastern Shore
Marlene Jack	Exxon	Jackson State University
Gerald Russell	Exxon	Jackson State University
Timothy Watson	Exxon	Virginia State University
Alicia Barnes	MISIP	Hampton University
Naomi Scott	MISIP	Hampton University
Kim White	MISIP	Hampton University
	1987	
Roderick B. Buck	Exxon	Hampton University
Henry E. Calvert	Exxon	Jackson State University
Kateri J. Kirby	Exxon	University of Michigan
Sylvester R. Young	Exxon	Hampton University
Kim Waymer	MISIP	Hampton University



Graduate students David Eggleston (left) and Livingston Marshall utilize a beach seine to collect pipefish for an experiment.

Visiting Scientist Program

In a continuing effort to broaden and share its own research knowledge, the School of Marine Science has in recent years begun a program to attract nationally- and internationally-known scientists to visit VIMS on a regular basis. The program continued during 1986-1987 with the visits of seven experts from various fields of study. Such specially-selected individuals from leading centers of research bring valuable new ideas and techniques from other institutions, and contribute to improving the capabilities of the Institute.

As a leader in the United States in estuarine and coastal research, the Institute also believes that it has much to offer from its own ongoing research projects, and each visit anticipated under the program is therefore expected to offer mutual benefits to the Institute and the visiting scientist.

The program is competitive, with selection of recipients based on: 1) accomplishments of the individual; 2) applicability of the scientist's areas of expertise to research being conducted at VIMS; and 3) potential to develop further the Institute's centers of excellence in sedimentology, pathobiology, toxicology, environmental chemistry, and other areas of directed research in the Institute research plan. The Visiting Scientist Program is funded under grants from Sovran Bank, N.A. and the Edmondson Foundation.

Participants in the 1986-1987 Visiting Scientist Program

Dr. Arieh Wishkovsky Fulbright Scholar Petah-Tiqua Israel	Immunology July 1987 - August 1987 (2 months)
Dr. John Grizzle Department of Fisheries Auburn University Auburn, Alabama	Histopathology April 1987 (1 month)
Dr. John Widdows Principal Scientific Officer Institute of Marine Environmental Research Plymouth, England	Shellfish Ecology May 1987 (1 month)
Dr. Jens Borum University of Copenhagen Hillerod Denmark	Plant Ecology October 1986 (1 month)
Dr. Labbish Chao Department of Oceanography University of Rio Grande Brazil	Fisheries Ecology March 1987 -June 1987 (4 months)
Dr. Jae-Kyung Oh Department of Oceanography Inha University Inchon, Korea	Geological Oceanography August 1986 - July 1987 (11 months)
Dr. John Stegeman Department of Biology Woods Hole Oceanographic Institution Woods Hole, Massachusetts	Toxicology November 1986 (1 week)

Library

A series of extraordinary collections that were donated as gifts during 1987 greatly strengthened the holdings of the library. The first was a complete set of the International Whaling Commission publications, generously provided by the Japan Fisheries Association.

Another was the fine ichthyology library of Dr. Robert H. Kanazawa, which was donated by his son, David. Dr. Kanazawa was affiliated with the Museum of Natural History at the Smithsonian Institution. Third, Dr. Carl N. Shuster donated a number of miscellaneous reprints, and also plans to give his extensive collection on **Limulus**, his specialty. An outstanding collection of works on parasitology was donated by Dr. Robert Hutton of Mt. Solon, Virginia.

One of the few available thirty-volume sets on the U.S.-Canadian arbitration of the disputed George's Bank boundary was acquired and donated by Dr. William J. Hargis, Jr., who also gave the library an extensive collection of books, reprints, and other materials.

Finally, an invertebrate book series and some classic volumes were sent to the library by James Melvin, a VIMS alumnus.

The library's research capabilities and computer services continued to be improved during the year. The Chesapeake Bay Bibliography revision was completed and the database reloaded using FYI 3000 software. The library provides on-line searching for anyone seeking specific information on the Bay. In addition, updated tapes were sent to the Chesapeake Bay Program's information system in Annapolis for public access by remote terminal.

Another innovation was the acquisition of a new federal CD-ROM which uses a compact disk to store extensive data. VIMS has obtained the **Aquatic Sciences and Fisheries Abstracts** Data Base from 1985 to the present in this format. We will now be able to search this file an unlimited number of times for the cost of the disk as opposed to having to pay a charge for each search on a commercial on-line system such as DIALOG. Another benefit is the menu-driven search software which makes the system easy for anyone to search without special training. Presently the CD-ROM is run from our M300 microcomputer, though we hope to secure an additional micro and move it and the CD-ROM to a more public area in the Library.

The librarians undertook a major examination and revision of the serials subscriptions, discontinuing some titles and adding new ones in order to develop a more efficient, current, and relevant serials list.

During May, the VIMS library hosted the annual spring business meeting of the Virginia Chapter of the Special Libraries Association, which featured a progress report on Virginia's Chesapeake Bay initiatives by the coordinator of the Virginia Council on the Environment.

Library Holdings at the end of FY 1986-1987:

Number of periodical titles	800
Bound volumes (periodicals and books)	38,466
Other holdings (maps, charts. etc.)	3,100

Interlibrary Loans FY 1986-1987:

Provided to other libraries	263
Received from other libraries	648

VIMS Computer Center

The central computer system underwent three upgrades in the past year. In August 1986, the central processor, a PRIME 9955 was upgraded to a PRIME 9955 model II, which at that time represented the most powerful computer manufactured by PRIME Computer, Inc., with a rated speed of 5 MIPS (million instructions per second). At the same time, the size of main memory was increased to 16 megabytes. During the year, the lack of disk storage space became increasingly serious, causing considerable impact on productivity of some research projects. In June 1987, an additional disk drive was installed, adding a further 495 megabytes of storage. This brought the total disk space to 2,075 megabytes. This addition eased the situation, but it is expected that further disk space will be required in the coming year.

As well as providing central computing power, the computer system represents a central repository for the scientific data collected in the many activities at the Institute. Computer Center personnel have been working with scientists assisting in the development and creation of data bases and data management schemes. Storing data on the central system takes advantage of the regular back-up procedures done by the Center's operator; furthermore, the data is thereby made available to a wide variety of investigators at the Institute.

Many individual scientists use personal computers in their own offices and laboratories. The Computer Center exercises control over the acquisition of personal computers to ensure that they can communicate efficiently with the central system.

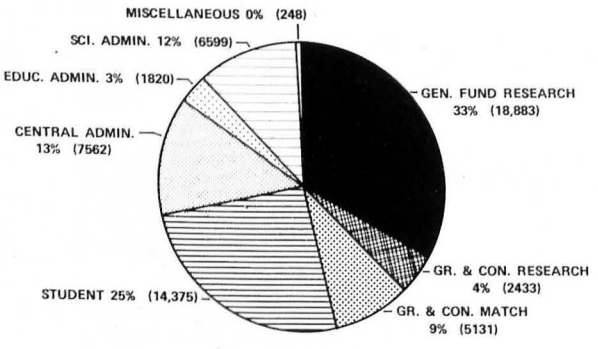
Technical support has been provided to research programs including:
applications software development and modification; interfacing instrumentation with the central system; and image analysis of photographic core data.

Computer Center faculty have participated in the educational program of the School of Marine Science by teaching regularly scheduled courses, serving on academic committees, and providing informal instruction.

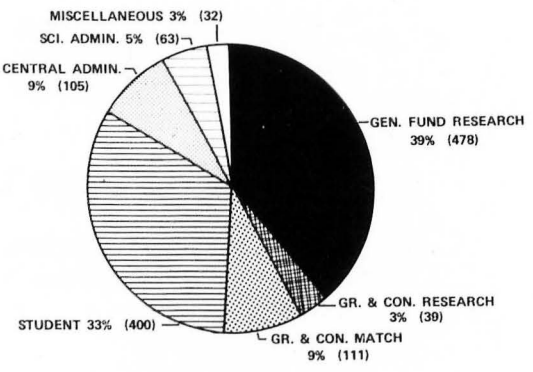
The following pie charts show the amount and distribution of computer usage in the past fiscal year. "Total Hours Logged-in" refers to the total time spent by the computer users at terminals throughout the Institute during the year. The total of 57,051 hours is equivalent to some 27 man-years. The distribution of this effort among the various general Institute activities is shown in the first chart.

"Total Computer Processor Hours" refers to the total time spent by the central processor unit in computing and processing data. The total for the year was 1,228 hours and the distribution is shown in the second chart.

TOTAL HOURS LOGGED-IN



TOTAL COMPUTER PROCESSOR HOURS



Vessels Support Center

The acquisition of the R/V BAY EAGLE, a new 65 foot research vessel highlighted several changes in the vessel organization during the past year. Built by Cam Craft, Inc. at Crown Point, Louisiana, and purchased by VIMS in February 1987, the crew boat adds another dimension to the vessel fleet.

The BAY EAGLE has increased our capabilities to deploy and retrieve large and heavy payloads, work in sea conditions that are marginal for our other vessels, utilize different types of scientific gear in one cruise, and comfortably accommodate our scientific staff during extended cruises.

As a result of coordinated planning by VIMS' scientific and vessel staffs, the BAY EAGLE has now been converted into a refined scientific work platform. Modifications by vessel personnel resulted in important cost savings for the Institute.

R/V BAY EAGLE Specifications

Length	65 ft.
Beam	18.5 ft.
Draft	4.5 ft.
Cruising speed	18 knots
Range	400 nautical miles
Propulsion	Two 12V71 Detroit diesels
Generator	20 KW 271 Detroit diesel
*Overnight accommodations	2 crew, 5 scientists
Lab space	5' x 12' wet lab 8' x 15' dry lab Scientific navigation station
Working deck	17' x 22'
Rigging	Mast/two booms with hydraulic boom winches

*Vessel is licensed for 36-day trips.

The year brought changes for the VIMS Dive Program. VIMS has become a member of the American Academy of Underwater Science (AAUS), and this affiliation assures reciprocity between other colleges and universities having similar diving programs.

Also, VIMS has acquired an underwater video camera and monitor which provides the scientific staff with a valuable tool for underwater observation and research.

Throughout the year, the Radio Communication System is used daily in the Vessels Support Center. This year VIMS added a new Base Radio System which enables monitoring of vessels in a 70-mile radius. A phone hook-up, allowing vessels to call direct without the use of a marine operator will soon be in operation.

The small boat fleet was supplemented with three new trailerable boats in the 18 foot class, replacing some aging craft.

Research

During 1983 the Virginia Institute of Marine Science inaugurated a comprehensive ten-year research plan designed to address the most important management issues facing the Chesapeake Bay system. The research activities reported here center around programs identified in the ten-year plan. These encompass fifteen research programs and eight monitoring programs, focusing on this overall goal: "To conduct general and applied research for the purpose of providing timely and accurate information to the Governor, General Assembly, State and local agencies, industry and citizens of the Commonwealth of Virginia regarding utilization, conservation and enhancement of the resources, both living and non-living, of the Chesapeake Bay system and the coastal waters of the Commonwealth."

The principal uses of this plan are:

- *to identify the scope of research needed to meet the requirements of the Commonwealth, and in particular to focus on those problem areas needing the most urgent attention;*
- *to provide a planning mechanism for efficient programming of State funds, and to identify those research areas where particularly aggressive effort should be placed in seeking extramural funding;*
- *to ensure that any pursuit of extramural funding is controlled and within the context of a long-range coherent plan; and*
- *to identify the additional personnel and equipment resource needs which must be obtained for satisfactory completion of the coherent plan.*

Program I. Investigate the fisheries of Virginia and factors affecting fluctuations in abundance.

One main goal of fisheries' research at VIMS is to develop a better understanding of the causes for fluctuations in abundance of juvenile crabs, oysters, and various fishes that will become available for harvest subsequently. This understanding will allow forecasts to be made that can benefit many segments of the fishing industry and enable them to prepare in advance for good or bad seasons. Forecasts can also be used by regulatory agencies to develop Fisheries Management Plans because they provide the necessary recruitment indices.

Bivalve Ecology. The bivalve ecology group at VIMS continued to examine a diverse range of problems relating to the Virginia oyster (*Crassostrea virginica*) fishery. These included studies of larval response to depletion of oxygen and changes in salinity, of gametogenic development and fecundity of oysters, of predators upon oysters, and completion of the field program to examine the influence of fouling community development on the settlement of oysters on "planted shell" in the Potomac River.

The influence of low oxygen on larval and post larval stages of the oyster is of concern in that the seasonal depletion of oxygen in the Bay over-

Dr. Fu-Lin E. Chu is currently investigating the metabolism of dietary fatty acids in oysters under a grant from the National Science Foundation.

laps with the oyster spawning season. Oyster larval swimming was examined in a regime of decreasing oxygen concentration. Surprisingly, it was found that a gradual decrease in concentration from 100% to 9% saturation (at 25°C and 20ppt salinity) did not cause a cessation of swimming, although further extension of the period of low oxygen exposure did result in cessation of active feeding and eventual mortality. Competent to metamorphose larvae retained their competency even after a 24-48 hour exposure to 20% saturation. Extended exposure at 20% saturation or lower oxygen concentrations resulted in decreased competency. Oyster larvae have a limited capability to withstand oxygen stress. In addition to low oxygen stress, the swimming behavior of oyster and other bivalve larvae is affected by salinity. We have recently begun a series of experiments to examine the influence of salinity on bivalve larval swimming. Experiments conducted in 1985 and reported in the 1986 annual report suggested that larvae respond to salinity gradients at the mouth of the James River and that this response may contribute to their retention in the James River. We are expanding these experiments to gain a broader perspective of the role of salinity in determining the distribution of bivalve larvae. In addition to examining the larvae of oysters, which occupy a broad salinity range, we are examining the species *Rangia cuneata, Mulinia lateralis* and *Spisula solidissima*. These species encompass the salinity range of the native oyster but do not overlap extensively with each other.

We continue to examine the reproductive activity of adult oysters in the James River. An extensive collection of material was made in 1984. Using this material we have developed a quantitative method to compare the area of developing gonad in histological cross-sections to total cross-sectional area. Surprisingly, this has not been done before despite the requirement for such a technique in comparative studies. As mentioned in the section on monitoring, the settlement of oysters in the James River in 1986 was poor. We are investigating whether or not this was related to a possible lack of adequate spawning by adult oysters in the James River. A method has been developed to count eggs in oysters collected at regular intervals of time from a series of stations along the James from Horsehead (upstream) to Dog Shoal (downstream). The egg counting method is being compared with more traditional, simpler methods of assessing oyster condition. At this time it appears that spawning was depressed in the James during 1986. We are continuing this study into 1987 to provide a base for comparative assessment of data, and a complete analysis of data will be finished by late 1987.

Loss of oysters to predators following settlement is a significant problem to which only limited remedial measures can be applied. Nevertheless, these losses must be quantified in order to understand better the fishery and its management. Gastropods (snails) can be significant predators on oysters. A close examination of the Wreck Shoal area revealed a very high diversity and concentration of gastropods: up to 11 species and 231 individuals were found in a sample area of only 5 inches diameter. Dominant among these was the snail *Boonea impressa* which has recently been implicated by workers in the Galveston Bay region in the transmission of *Perkinsus marinus*.

Crabs are also known to prey on small oysters. In laboratory experiments the relationship of oyster density, oyster size and temperature to predation by the blue crab, *Callinectes sapidus*, has been examined. Predation rate increases with increasing prey density and temperature; however, predation is surpressed below 16°C. At low temperatures and prey densities predation is reduced (this corresponds to the field situation in autumn and winter). Further, once oyster length exceeds 30mm analysis reveals that predation becomes less profitable for the predator and predation pressure decreases. Unlike the blue crab, the cownose ray, *Rhinoptera bonasus*, tends to cause massive localized mortality rather than widespread mortality. Surprisingly little is known about this large migratory schooling ray, yet its impact on oyster plantings is common knowledge. In 1986 we started a program to quantify the impact of ray predation on oysters in the Virginia portion of the Chesapeake Bay. Aerial surveys were conducted in conjunction with the VIMS turtle survey to estimate numbers of rays swimming at the surface. In addition, radio and ultrasonic telemetry were investigated as methods to quantify the proportion of time spent at the surface and thereby provide

correction to the aerial survey data in assessing population size. Both techniques proved promising and are being incorporated into an expanded program of study in 1987.

Climate and Fisheries. Research on the effects of climate variability once again focused primarily on summer flounder (fluke) and croaker, and secondarily on spot. Analysis was also completed on fifteen years of oyster index data. Because information is lacking on the recruitment of finfish (particularly flounder) in Virginia waters, field collections were conducted throughout the year. A systematic sampling regime was established based on preliminary data collected in early 1986. In order to determine when, where, how, at what size and how many summer flounder recruit to Virginia, and thus to define their nursery areas, we sampled four sites, one each day, every other week for 12 months. Two sites are inlets on the seaside of the Eastern Shore, one in a creek on the bayside of the Eastern Shore, and the other at the mouth of a river on the western shore of the Chesapeake Bay. Within each site, habitats were divided and sampled according to depth (shallow vs deep) and substrate (sand vs mud). Our findings have supported last year's preliminary results, that newly recruited summer flounder are initially found in shallow mud habitats.

Collections at the four sample sites indicated recruitment times and suggested recruitment mechanisms which change seasonally. Croaker, which spawn from August to November, could be found entering the seaside embayments as small as 5mm in the fall. They did not recruit to the western side of the Bay until several weeks later when they were 10mm-20mm. Their recruitment was continuous, as indicated from their small size, from September through December, with peak abundance in December.

Flounder spawn north of Cape Hatteras from September to December, but few flounder recruited to any of the four sites in the fall. Of those captured, the majority were on the seaside in the marsh channels and were 15mm-20mm. Larger numbers of recruits were collected in the spring. These were first collected in April within the Chesapeake Bay, indicating transport from a southern source with arrival at the Bay mouth preceding appearance on the seaside of the Eastern Shore. Numbers of new recruits peaked in May and June at all sites.

Spot are known to recruit to the Chesapeake Bay in the spring. Newly recruited spot, 20mm-25mm, appeared in late April and May, following their January to March spawning season. Spot, like spring recruits of flounder, were collected in Bay samples prior to being caught on the seaside of the Eastern Shore. Spot recruitment seemed to take place in waves, with all fish being within 2mm-3mm of the mean size. Cursory observations indicate that spot recruitment followed periods of southerly winds.

Lengths were recorded for all three species and will be analyzed for growth rate and temperature relationships. As usual, croaker disappeared from our sample sites during the winter and reappeared after water temperatures had warmed. The croaker year class is not excessively abundant following a moderately cold winter. These same year classes of croaker flounder and spot, as well as the incoming ones, will be followed through 1987-1988 by monthly sampling at these same sites. This should provide additional growth and abundance information on the 1986-1987 year classes and recruitment data on the 1987-1988 year classes.

Time series analyses of oyster condition indices for the period 1970-1985 for the major Chesapeake Bay tributaries in Virginia have been completed. Analyses include consideration of condition index vs pea crab infestation rates, growth/size, days of growth season (temperature above 10°C but below 22°C), and days of salinity above 4ppt. The time series analyses have allowed an examination of long-term trends, seasonal fluctuations, and random events. A major finding has been that the trend in condition index in the Rappahannock River is down, whereas it is up in the James River.

Chesapeake Bay Finfish Stock Identification. Management plans by the Atlantic States Marine Fisheries Commission have identified the lack of knowledge of the east coast stock structure for bluefish, weakfish and flounder as a primary problem in plan development. Accordingly, a stock identification program for these species was initiated with funding through the Virginia Marine Resources Commission from the Fish and Wildlife

Service as part of the federally funded research programs under the Fish Restoration and Management Act (Wallop-Breaux Act).

Bluefish stock identification was conducted by the NOAA Sandy Hook Marine Laboratory during the 1960-1970's, but unfortunately all data were lost during a fire which destroyed that laboratory.

Their analyses were listed by morphometric measurements (body proportions), whereas in our study morphometric measurements and electrophoretic analyses are made of each fish.

Anadromous Fishes. Research on anadromous fishes (those which spawn in fresh waters and mature in ocean waters) during this past year focused on: 1) estimating the fishing effort expended for American shad, alewife, blueback herring and striped bass; 2) obtaining striped bass for hatchery culture; and 3) the tagging and releasing of striped bass in the James River.

Effort data are a basic ingredient in many mathematical models concerning exploitation and mortality rates, and stock size. Pound net effort was estimated from frequent aircraft flyovers, and gillnet fishing effort was collected by observers in small boats and from logbooks kept by cooperating fishermen. Effort data were also of value in population dynamic studies of nonanadromous species. These data in conjunction with the monitoring data (see section on monitoring) for anadromous species were used to estimate: 1) relative abundance (catch-per-unit-of-effort) by year class; 2) year class biomass and the cumulative biomass of a year class in a fishery; 3) exploitation and mortality rates; and 4) growth rates from back calculations on annuli of otoliths and scales.

In cooperation with the Virginia Commission of Game and Inland Fisheries (VCGIF), Virginia Marine Resources Commission (VMRC) and the U. S. Fish and Wildlife Service (USFWS), VIMS participated in a program to capture striped bass brood stock. The major objective is to determine if hatchery reared fish will enhance striped bass abundance. The initial efforts were mainly administrative; field efforts were limited to a pilot study of capture, holding, and transportation methods. In this continuing program, VIMS will capture brood specimens and VCGIF will transport the fish to a state hatchery for spawning. Subsequently, the young fish will be transported to USFWS hatcheries, where at 8 to 10 inches the fish will be tagged and released in the natal streams. VIMS will monitor the success of the stocking program by periodically sampling striped bass in the natal streams and adjacent waters.

The objectives of the mark-recapture studies are to: 1) evaluate exploitation within and outside the Chesapeake Bay region; 2) assess coastal migrating patterns of these species; 3) assess the degree of fidelity to the river-of-capture in subsequent spawning seasons; and 4) contribute to the present age-growth and size at maturity data base. The ultimate goal of all federal and state agencies concerned with anadromous fishes is the development and implementation of rational management plans to restore and enhance anadromous fish stocks. Toward this end, the major goal of the VIMS program is the development of stock assessment models that will give Virginia fishery managers state-of-the-art quantitative tools.

Crustaceology. FY 1986-1987 was a year of restructuring and program development under Dr. Romuald Lipcius, new head of crustaceology studies. Various programs were initiated with support from the Commonwealth of Virginia, National Science Foundation, Earthwatch-Center for Field Research, and the Smithsonian Institution. Specific programs in the Chesapeake Bay undergoing development are: 1) predator-prey dynamics of blue crabs, mud crabs, epibenthic fish and bivalves; 2) recruitment dynamics of blue crab postlarvae and juveniles; 3) distribution, abundance and movement patterns of the blue crab and their relation to Virginia fisheries; 4) modelling of population dynamics of the blue crab and its key prey, including fishery models useful in management; and 5) collection and analysis of juvenile blue crab data from the VIMS trawl survey.

In addition, the Crustaceology section with support from the Caribbean Marine Research Center has established international fisheries programs on spiny lobster and queen conch in the Caribbean, thereby providing scientific expertise to underdeveloped nations lacking qualified fishery scientists.

Pound Net Program. Funds acquired from the Chesapeake Bay Stock Assessment Committee were used to characterize the Chesapeake Bay pound net fisheries. Operational procedures were described for commercial pound net fisheries on the water and at the dock. Potential sites for intercepting biological data were identified. Sources of variation in catch composition data were identified and their comparative magnitudes evaluated. This information provides a basis upon which to build programs to collect basic life history/population dynamics data on adults.

Shark Research. The shark program was continued this year in a cooperative effort with the Virginia Beach Sharkers, a recreational fishing group. The Sharkers donate all sharks captured in their annual tournament for study. VIMS scientists remove vertebrae for age determination and examine feeding habits and sexual development in sharks landed at the tournament. These data are used to complement data derived from sharks captured as part of the continuing VIMS long-line project which has made more than 200 collections in Chesapeake Bight since 1973.

In addition to life history studies on sharks, VIMS scientists continued their association with the National Aeronautics and Space Administration and studied hydrodynamic lift and associated drag in sharks, tuna and billfishes. New findings suggest that the complex geometry of the fairing where shark fins meet the body is similar to that found on the conning towers of new classes of Soviet submarines. Studies of deep-sea sharks were expanded with acquisition of very rare specimens collected as deep as 3 km under the sea. Current studies are examining the hypothesis that maximum depth of occurrence of sharks is controlled by energy availability.

Turtle Research. Research on sea turtles continued in 1986-1987. Efforts centered on tracking sea turtles using radio and sonic transmitters to study migration, surfacing behavior and movements. In addition, one turtle was tracked at sea in the fall with a transmitter monitored by satellite.

Aerial surveys were continued to obtain estimates of sea turtle standing stocks in Chesapeake Bay; stranded sea turtles were counted to monitor sea turtle mortality. Live turtles supplied by pound net fishermen were examined to determine the state of health of turtles during different times of the year. Blood chemistry of these turtles is being analyzed as a possible indicator of physical condition.

In general, when turtles first enter the lower Bay in early summer, many are in poor condition compared to turtles found throughout the Bay later in the summer. Studies of age and growth in sea turtles were continued using tetracycline injections as a bone marker to verify rate of bony ring formation. Preliminary results show that only one ring is deposited per year. Thus, ring counts are probably an accurate indicator of age.

The U.S. Navy funded studies on distribution of sea turtles at two sites, one within the Bay and the other offshore Virginia Beach, both of which are being considered for use of the U.S. Navy's EMPRESS II facility (used for testing equipment sensitive to electromagnetic pulses). The site within the Bay only had a few turtles during early June. None were found during periods proposed for testing. The offshore site contained heavy densities of sea turtles in May and in the fall during migrations, and a resident population during the summer. Other preliminary studies suggested that electromagnetic pulses altered magnetic material found within the heads of turtles. This may adversely impact turtle migration.

Ichthyology Museum. The VIMS museum fish collection continued to serve as a repository for scientific voucher specimens. In addition to specimen loans, gifts, and trades to scientists all over the world, the collection is used as a teaching aid by VIMS Advisory Services personnel, and museum curators also identify many fish specimens for the general public in the course of the year.

Gulf Coast Fishes. This work continues and has emphasized in the past year life history/population dynamics work on sea robins and Atlantic threadfin. These have proven to be short-lived fishes with high mortality rates and rapid turnover of biomass.

The range of fishes in the Gulf of Mexico extends into waters of the south and mid-Atlantic, so these studies provide insight into Virginia and East Coast resources as a whole.

Microbiology of Shellfish and Shellfish Growing Areas. Research efforts continued to assess the validity of the fecal coliform indicator used to classify shellfish growing areas. Studies performed at VIMS and other institutions suggest that this indicator is an inadequate predictor of public health risk. Work has continued on the role of environmental factors such as light, salinity and temperature on survival of the fecal coliform indicator and human pathogens.

VIMS microbiologists are now participating in an EPA-sponsored shellfish feeding study to validate the predictive value of the current fecal coliform growing area standard and to evaluate alternate indicator organisms. Raw shellfish collected from approved local waters are fed to volunteers who are then subjected to a comprehensive epidemiological analysis to screen for verifiable enteric disease statistically different from various control groups. This is the first study to be performed to validate quantitatively the public health significance of the current shellfish growing area standard.

A three-year research program on the microbiology of shellfish relaying, sponsored by NOAA Sea Grant, was completed. The last year consisted of an evaluation of containerized relaying of the hard clam, *Mercenaria mercenaria*. On the basis of our microbiological studies, the Virginia Marine Resources Commission and the Virginia Department of Health developed regulations permitting containerized relaying of hard clams. In addition to demonstrating the markedly superior economic advantages of this process, important data on the *in situ* self-purification of virus and selected microorganisms, and the effect of water quality on self-purification was obtained.

VIMS microbiologists continued to be active technical consultants to the Interstate Shellfish Sanitation Conference (ISSC), a national group representing the industry, state and federal regulatory personnel. Recommendations of the government/industry sponsored "Shellfish Microbiology Workshop," held at VIMS in 1986, were presented to the ISSC at the annual meeting in Seattle, Washington.

This year VIMS microbiologists began a comprehensive program to address the problem of shellfish closures in growing areas in the absence of known point sources of human sewage. This problem, which has rapidly become one of national concern, has significantly reduced growing area acreage for direct harvesting of shellfish. Basic questions which are being examined relate to the contribution and public health significance of animals as sources of indicator bacteria and human pathogens; the importance of seasonal precipitation on the microbiology of growing waters; and the validity of candidate indicators proposed for the differentiation of human from animals sources of contamination.

Program II. Investigate and define the distribution of benthic animals and communities and their interactions with the biological, physical, and chemical environment.

The objectives of this program are to evaluate biologically mediated physical and chemical interactions at the benthic boundary layer; to evaluate man-induced effects as they impact the benthic environment; and to evaluate the resource value of different bottom habitats. The objectives and many of the field operations of this program are closely interwoven with the Benthic Boundary Layer Program (Program XI). Activities during FY 1986-1987 were vigorous and advanced along several fronts.

Multispecies laboratory systems (microcosms) are increasingly being used to assess environmental effects of xenobiotic compounds in aquatic ecosystems. Synoptic microcosm and field experiments were conducted using natural macrobenthic assemblages from two North American temperate estuaries between 1982 and 1985. Criteria for establishing, conducting and interpreting the results of benthic microcosm tests were determined. Categorization of species into ecologically based guilds provided a means of 1) obtaining a manageable number of response variables; 2) assessing functional changes in the compositions of the communities; 3) evaluating those components of the community for which the microcosms were good analogs of the natural field assemblages; and 4) making comparisons between

results from geographically distant locales with differing species compositions.

Based upon comparisons between unmanipulated controls from the laboratory and field sites, we find that only certain components of a community are modelled well in the laboratory (such as species richness and the numerical abundances of some guilds), and we propose that these components alone should be used to predict environmental impact from laboratory toxicity tests. A series of experiments conducted with pentachlorophenol were used to test these predictions with benthic communities from the Chesapeake Bay and from Apalachicola Bay, Florida. The results indicated that this approach towards assessing environmental hazards provides a promising avenue for future work in ecotoxicology.

A major study of spatial variability in benthic communities in the Chesapeake Bay and on the adjacent continental shelf was also completed. The benthic communities at the Wolf Trap area of the lower Bay were found to be very diverse and abundant. Broad areas were very similar in all community parameters measured. The faunal composition at the Wolf Trap Region was indicative of a mature or advanced successional stage community. The dominants were large and long-lived species characteristic of an equilibrium life history, as opposed to small short-lived species that have opportunistic life histories.

There were no wide fluctuations in abundance of any of the species. However, there was a very strong trend of populations decline from a high in the fall of 1983 to a low in fall of 1984. For most of the species this decline was monotonic. The strongest gradients in the fauna followed the east to west mudding of the sediments, with the eastern side of Wolf Trap being about 55% fine sand and the western side about 25%. This sediment gradient accounted for most of the spatial variability in communities.

The biogenic structure of the Wolf Trap Region sediments was very well developed. Sediment profile images indicated intensive reworking of sediments down to at least 12 cm. While the level of reworking varied seasonally, the benthos was the major force affecting the physical structure of the surface sediments.

The benthic communities at the area north of Rappahannock Shoals were found to range widely in diversity and abundance. Sandy areas to the east were overall more diverse and had higher abundances relative to the muddy areas. There were very sharp breaks in the communities in the Rappahannock Region due to changes in sediment type. The faunal composition at the Rappahannock Region was generally indicative of an early successional stage community. The communities were made up of species with opportunistic life histories.

There was no overall trend in the populations of the dominant species at the Rappahannock Region. Populations at the Rappahannock Primary Site were almost always higher than the Rappahannock Alternate Site. The strongest gradients in the fauna followed the west to east mudding of the sediments; the western side of Rappahannock being about 1% sand and the eastern side about 90% in the north and 20% in the south. This gradient accounted for much of the spatial variability in the communities, but there was also a north to south gradient in sediments that influenced community structure.

The biogenic structure of the Rappahannock Region sediments was extremely variable, ranging from complete lack of biogenic activity to well developed structure. The areas of most intense biogenic activity were mixed sediments. Mud sediments were very low in biogenic activity, as were the higher energy sand areas. Seasonal changes in biogenic structures were most pronounced to the north of the Rappahannock Shoals.

Distribution and ecology of continental shelf oligochaetes are poorly understood. At times they are dominant species and play an important role in community structure. From 1975 through 1977, baseline ecological studies were conducted in the Middle Atlantic Bight prior to oil exploration activities. A total of 38 species in three oligochaete families were collected. Of this total, one family and 29 of the species were undescribed at the time of collection. We have over the past 10 years described all the new species and have now summarized the results.

The most abundant and widely distributed species were *Limnodriloides monothecus*, *L. medioporus*, *Bathydrilus longus*, *Phallodrilus biprostatus*, and *Tubificoides diazi*. No single species dominated the oligochaete fauna. All the

oligochaetes species responded to changes in physical parameters over the shelf similarly to the total macrofauna. Seasonal trends within the oligochaetes were not found. Species that preferred coarser sand sediments were all small interstitial forms. The finer sand and eurytopic species were all burrowers. Zoogeographically, the Middle Atlantic Bight oligochaetes were predominantly temperate (16 species) with some southern species (8). Seven species were broadly distributed from the Caribbean to Massachusetts or around the world. Seven species were only known from the area studied.

Other developments in the benthic ecology program include: 1) developing a quick method of assessing relative benthic habitat value (i.e. for application to dredging), utilizing an existing data base and bottom and REMOTS photographs; 2) measuring input of Be for a year; 3) identifying and explaining, in terms of controlling physical and geological factors, the distribution patterns of blue crab overwintering; and 4) observing changes in feeding strategy of surface deposit feeders as related to sediment-transport-induced mediation by way of field observations.

Program III. Develop an understanding of plankton processes in the Chesapeake Bay system and Virginia's coastal waters.

Innovative Technology and Methodological Development. It is widely acknowledged that current manual identification and enumeration techniques are too slow and labor intensive to cope with the high resolution sampling needed to characterize the responses of the plankton community to complex and varying hydrographic conditions found in subestuaries of the Chesapeake Bay, such as the James and York rivers, and in the Bay itself.

In addition, sampling techniques which are adequate for wide expanses of homogeneous water such as in the open ocean do not provide sufficient spatial or temporal resolution to characterize the dynamics of recurring changes in vertical structure and frontal and convergence zones in estuarine and coastal waters.

In response to this acknowledged need we have started this project with the goals of developing and/or acquiring automated identification and enumeration technology as well as improved sampling technology for both autotrophic and heterotrophic plankton over the full size spectrum from bacterioplankton to large zooplankton. Early results elsewhere indicate the feasibility of digital image analysis as a technique for processing natural plankton samples rapidly and accurately.

At the beginning, we investigated the use of epifluorescence microscope and color discriminating video digitizing for enumeration of phytoplankton and bacteria. Through use of funds from the Federal government, we have acquired a dedicated automated epifluorescence microscopic capability and a digitizing/computing instrument capable of 1) rapidly (1/30 sec) digitizing either microscopic or macroscopic images simultaneously in three colors at high spatial and intensity resolution; and 2) rapidly performing digital analyses of those images.

Epifluorescence microscope images of planktonic microorganisms reveal considerable information concerning the population abundance, biomass, community composition and physiological condition of these cells. The system in use can store images in separate red, green and blue color planes in a format of 512 x 512 pixels per color plane.

A variety of established image processing techniques, such as image averaging, thresholding, bit-masking, and segmentation, are used for analysis of 2-dimensional cell images from the epifluorescence microscope. The use of a color video and digitizing system allows the measurement of pigment content and composition and the arrangement of chloroplasts, nuclei and other intracellular organelles for large numbers of individual cells.

This information, along with size and shape measurements, will be used to study the physiological adaptations of cells to changes in environmental factors such as nutrients and light. Natural planktonic populations can also be counted, sized and classified according to specific trophic and taxonomic types. This system will enable relatively large numbers of cells to be analyzed without the

tedium associated with visual counting and measuring methods, so that small scale temporal or spatial changes of these populations can be studied.

The most promising approach to high resolution zooplankton sampling seems to be photography. Photographs of silhouetted oceanic zooplankton taken from a towed submersible vehicle have been published. These photographs were taken with a shutterless camera, the exposure controlled by the light from a strobed light source. These images seem potentially amenable to digital analysis. If so, this combination would provide a system for obtaining and processing the quantity and quality of samples needed. Even if the acquired images require human interpretation, the possible temporal and spatial resolution far exceeds any known towed net system, while sample handling and preservation is reduced to film processing. We are therefore seeking outside funds for this photographic capability.

Funding from the Virginia Environmental Endowment will support a comparison of the epifluorescent and Utermohl microscope techniques for enumerating natural estuarine plankton samples during the next year in collaboration with Old Dominion University scientists. Epifluorescence microscopy is widely perceived to have several advantages over the traditional Utermohl cell counting technique including the capability: 1) to enumerate more accurately the abundant and significant picoplankton (<2.0 μm) component of the phytoplankton community; 2) to differentiate between heterotrophic and autotrophic pico- and nanoplankton (2-20 μm); 3) to enumerate heterotrophic bacteria; and 4) to be combined with computer image analysis (see above). It is anticipated that the results of this year-long study will demonstrate the need to incorporate epifluorescent microscopy into the ongoing Chesapeake Bay phytoplankton monitoring program.

The primary goal of all three technique development efforts is to ensure that plankton research in Virginia is carried out with state-of-the-art methodologies which will improve the changes so that the data currently gathered will be useful well into the 21st century.

Chesapeake Bay Plume. A study of physical and biotic processes affecting the distribution and survival of larval fishes at the Chesapeake Bay entrance continues. The investigation funded by the National Science Foundation is being conducted in cooperation with the University of Maryland, and addresses the complex interactions between larval fishes, their principal predators and the physical environment. During summer 1985, scientists on board the VIMS' R/V LANGLEY coordinated plankton sampling with two NSF vessels in an attempt to survey small scale distribution patterns of fish eggs and larvae associated with the Chesapeake Bay coastal outfall plume.

Processing and analysis of the resulting 1,200 biological collections and attendant hydrographic data are nearing completion. A field and laboratory study on the hydrographic effects on potential fish egg predation by the lobate ctenophore *Mnemiopsis leidyi* at the Chesapeake Bay entrance confirmed that this gelatinous zooplankton species ingests fish eggs and revealed that changing patterns of potential predation at the Bay mouth are related to the complex hydrography of the plume.

Factors Affecting Survival of Early Life History Stages of Striped Bass. Laboratory experiments designed to test the acceptability of striped bass larvae as prey items for fish and invertebrate species known to have spatio-temporal coincidence with the spawning of striped bass were continued during spring 1987.

To date, juveniles and/or adults of nine species of fishes resident in the Pamunkey River have been observed to feed readily on striped bass larvae. The consumption rate on yolk sac larvae has been estimated for the satinfin shiner and spottail shiner. A cyclopoid copepod, *Mesocyclops edax*, has also been implicated as a potential predator of these yolk sac larvae. Using a low-light video system, predatory behavior and reaction distances of *M. edax* towards yolk sac larvae was measured. Preliminary results indicate that *M. edax* was able to detect a larva at a distance as great as eight copepod body lengths. The body region attacked was important in determining how long a larva would live. Eighty-eight percent of those larvae which were attacked in the head region died within half an hour, while larvae attack-

ed in other regions of the body often did not die within the 12 hour observation period.

The goal of this part of the study is to provide a descriptive model of attack behavior that can be applied to field collected estimates of predator-prey spatial coincidence. Efforts will be continued during the spring of 1988 to identify other potential predators, determine their predation rates and document natural predation.

During the time of peak striped bass spawning in spring 1987, we continuously sampled a patch of eggs for a 48 hour period in the Pamunkey River to determine natural egg mortality rates, to estimate egg viability, and to examine small-scale distribution of striped bass eggs. Subsequent to the location of a high concentration of eggs, we tagged the water with a fluorescent dye and followed the movement of eggs using an onboard fluorometer and navigational transmitters deployed onshore. Plankton sampling was synoptic with bottom trawls in an effort to document the co-occurrence of egg predators with the egg patch. Sampling resulted in 60 trawl and egg collections. Sorting and identification of this material is currently underway. Eggs are being enumerated and sorted into viability categories and age cohorts based on known developmental rates. Guts of fishes are being examined for the presence of eggs or larvae.

An additional objective of the time-series egg mortality experiment was to obtain preliminary data on the residence time and tidal transport of eggs in the Sweet Hall Marsh region of the Pamunkey River that represent primary spawning sites. Dye concentration data will be examined to reveal patterns of water parcel movement in this area. These data will be input into a computer enhanced graphics program designed to produce an enhanced "motion picture" of water parcel movement and egg distribution during the two complete tidal cycles of sampling. Additional deployment of dye is planned for September 1987 in order to evaluate the contribution of a secondary channel in Sweet Hall Marsh to an hypothesized loop in water movement between river mile 40-45. Such a loop current would enable eggs and larvae to remain in a favorable habitat for development without being swept seaward during critical pelagic stages.

Program IV. Describe and evaluate the tidal freshwater ecosystems of Virginia's major rivers.

Tidal Freshwater Wetlands. This program is designed to describe the structure and function of tidal freshwater wetlands. Work during the 1986-1987 fiscal year was focused on wetlands in the Pamunkey River basin, and included the following projects:

1. Description of the primary production of the overstory and understory in tidal freshwater swamp communities. This project was completed, and results of the work are now being utilized in the modelling project described below.

2. Description of the seasonal concentration of nutrients in plants and soils of the marsh communities. Data collection and analysis for this project continued during 1986-1987. Work has also been initiated on a computer model which will simulate the seasonal standing stocks and fluxes of nutrients within the wetland plant community. This work is designed to provide input to the system-level model described below.

3. Analysis of groundwater movement and related nutrient movement in tidal freshwater marshes. Intensive sampling for this project was completed during 1986-1987. Results are now being analyzed and utilized in construction of a simulation model of marsh hydrology.

4. Determination of the role of sedimentation processes in nutrient cycling on tidal marshes. Sampling for this project was completed during 1986-1987.

5. Measurement of the net production and turnover rate of *Peltandra virginica*. Sampling for this project was completed in 1986-1987 and results of the completed project are designed to support the modelling efforts described below.

6. Documentation and analysis of the waterborn nutrient exchange between marsh and river. This is a new project designed to investigate the net flux of nutrients in a tidal creek which drains a small, well-defined area of intertidal marsh. Sampling design and methodology were developed during 1986-1987 so the project could be com-

menced during the next year. Data from this project will support development of a system level model of nutrient movement in the marsh system. The results will aid the effort to fit the smaller submodels being developed as part of the projects mentioned above into a larger simulation.

7. Description of muskrat impacts on the marsh system. Additional evidence of the significance of muskrat activities was developed in conjunction with work on the other projects in this program. The population of muskrat dens was mapped in the study area during 1986-1987 and preliminary estimates of impacts on vegetation and hydrology were developed.

8. Analysis and simulation of the vegetative succession in marsh communities. This project was initiated last year and involves an effort to simulate the control both biological and physical factors exert on the long-term development of the marsh system. The project requires development of an extensive data set in support of the simulation. Sampling seasonal changes in the vegetative community on the marsh has occupied all of 1986-1987 and will continue into next year. Work on this project has stimulated several smaller studies on autecology and demography of selected plants within the marsh system.

9. Simulation of tidal freshwater wetland systems. This project is designed to aid in the design and direction of the various smaller projects. The principal effort is to develop a computer based simulation of marsh community dynamics which can address both seasonal and long-term trends in the system. At present the model remains a conceptual one with the simulation efforts directed at the submodels supporting the projects identified above. It is intended that this simulation effort will in part support the drainage basin level modelling project described below.

Tidal Freshwater Ecosystem. This portion of the program involves an effort to understand the relationship between the different components of the tidal freshwater river drainage basin and how they cumulatively affect materials passing downstream to the estuary. The approach is to develop a model of an entire drainage basin which has the capacity to simulate the consequences of modification of water, nutrients or sediments fluxes in the system. At present work on this project is directed at assembling the data sets required by the initial conceptual design.

Soils Metabolism and Nutrient Exchange Capacity. This is an ongoing study initiated in the spring of 1986 to determine the seasonal and spatial characteristics of marsh soils oxygen demand and nitrogen exchange capacity. On completion (Summer 1987), the studies will provide, in part, data necessary for assessing carbon and nitrogen mass balance for various marsh elevations and types. Coupling these results with other ongoing projects will allow evaluation of the role of tidal freshwater wetlands in the maintenance of riverine water chemistry and biological productivity.

Program V. Investigate structure and function of mesohaline marshes and submerged aquatic vegetation.

Mesohaline Marshes. The purpose of this project is: 1) to monitor the long-term development of man-made marshes; 2) to document changes and succession in floral and faunal communities; and 3) to evaluate the effectiveness of these marshes in replacing natural ones.

During 1983 a 10 m X 30 m grid system was surveyed and permanently marked in an eight acre study on Goose Creek, a tributary of the western branch of the Elizabeth River. Each of the 108 points have been sampled annually since 1983 to determine frequency distribution of species, characterize the plant communities, and determine the elevations at each point. These studies will continue in future years until some equilibrium within the plant community is established.

Studies designed to monitor the ichthyofaunal use of the Goose Creek marsh were initiated in 1985 and continue to the present.

Additional mitigation related studies are being conducted on a marsh created by the Navy in Willoughby Bay. The effort is focused mainly on the interspecific competition between the planted saltmarsh cordgrass, *Spartina alterniflora*, and the common reed, *Phragmites australis*, which previously inhabited the site. Common reed can be an extremely aggressive competitor in these situa-

tions, and we hope to be able to determine the environmental conditions necessary to control its spread.

Ecological Investigations of the Principal Factors Governing Submerged Aquatic Vegetation (SAV) Survival, Growth and Productivity in the Lower Chesapeake Bay. This program, initiated in 1984, has evolved into three principal areas of interrelated research: 1) lower York River environmental monitoring coupled with transplantation studies; 2) field and laboratory experimental studies of environmental regulation and controls on eelgrass photosynthesis and growth; and 3) ecological modelling and digital simulation analysis of eelgrass photosynthesis, growth and long-term community survival.

The working hypothesis common to all three areas (and which functionally links the various studies) is that submarine light, dissolved inorganic nutrients and temperature interact as principal components to govern not only the current distribution and abundance of eelgrass in the lower Chesapeake Bay and its tributaries, but also limit further development and expansion of grassbeds into currently denuded areas by either natural or artificial means. For the 1986-1987 fiscal year, the following studies were undertaken as either continuing or new projects.

Lower York River Environmental Monitoring. The physical, chemical and biological characteristics of five shallow water sites in the York River have been monitored at biweekly intervals since September 1984. These data are being used to characterize the lower reach of the river that historically supported dense stands of SAV, now limited to the downstream, near-mouth regions. Our goal through these as well as experimental studies is to develop the habitat quality criteria necessary for State and Federal regulatory agencies to effectively manage this resource. Reduced underwater light as well as increased water column nutrients characterize the upstream, unvegetated sites when compared to downstream, vegetated areas. However, whether these differences are sufficient to limit regrowth of SAV to these areas is an important question that we are attempting to answer.

The effects of reduced levels of light, a potential limiting factor on the growth and survival of eelgrass, are being investigated in a greenhouse facility modified for seagrass studies. Shoots of eelgrass planted in pots and placed in aquaria in the greenhouse are subjected to three levels of reduced irradiance corresponding to submarine light regimes at three sites in the York River which have historically supported stands of eelgrass.

There is a difference in underwater light quantity at these sites as well as a difference in the survival of transplanted submerged vegetation, with the sites characterized by the highest level of submarine light having the greatest survival rate. It has been hypothesized that storage of carbohydrate reserves necessary for growth is related to the quantity of submarine light. This hypothesis is being tested in microcosm experiments, where rates of growth of the aboveground and belowground portions as well as the accumulation of stored carbohydrate in the rhizome are determined in relation to the various light levels. These experiments are being carried out four times during the year beginning in May 1987, to determine the response of the plants at a range of temperatures during different periods of eelgrass growth.

Nutrient enrichment through cultural eutrophication is often cited as a major factor contributing to declines in abundance of submerged vegetation. Nutrient additions promote heavy fouling of leaf surfaces by epiphytic algae, which can reduce both the light and carbon available for macrophyte photosynthesis. Although grazing activity by macroinvertebrates has been shown to control epiphyte accumulation, the ability of grazers to limit epiphyte growth during periods of nutrient enrichment is unknown. A gradient of increasing nutrient concentrations exists in the York River estuary which corresponds with patterns of eelgrass loss, suggesting that nutrient enrichment may be partly responsible for limiting eelgrass growth in certain areas.

A study was initiated in January 1987, to address the interactive effects of nutrient enrichment and epiphyte removal by grazing on eelgrass productivity using both field and laboratory approaches. Mats of artificial eelgrass are placed regularly in the York River at several sites to determine rates of epiphyte accumulation under various

environmental conditions. The specific effects of nutrients and epiphyte removal on eelgrass growth are then tested in laboratory microcosms using the range of nutrient concentrations and grazer densities found in the York River. Finally, the mechanisms of interaction among invertebrate grazers, epiphytes, and eelgrass will be elucidated using short-term experiments to determine eelgrass productivity, epiphyte productivity, grazer food selectivity, and grazing rates. Results from all of these studies will provide information on some of the major factors hypothesized to control the growth and distribution of submerged macrophytes in Chesapeake Bay and similar habitats.

Simulation model studies indicate that submarine light intensity and temperature are the principal environmental factors that govern plant growth. For the lower Bay, these two variables determine both the distribution and abundance of naturally occurring grassbeds. However, relatively small decreases in the amount of light received by the plants result in a significant reduction in plant growth. With only moderate reductions in light the model predicts the plants will eventually die and the submerged vegetation will be lost. These simulation results parallel data and field observations made to date in the York River. Therefore, the model may prove appropriate as a predictive tool for management. The model is currently undergoing further refinement and testing, incorporating the variable light and nutrient concentrations observed in our habitat monitoring studies as well as the controlled, greenhouse-laboratory experiments.

In addition to these studies focused on water quality and correlative indices of interaction, sediment nutrient concentration and distribution with depth, bulk sediment physical properties, and exchange capacities at three York River sites (Guinea Marshes, VIMS, Clay Bank) have been determined at bimonthly intervals beginning in July 1986. These represent our first efforts at investigating submerged macrophyte - sediment interactions and the potential for sediment related properties and metabolic processes to influence eelgrass growth and survival in upriver, historically vegetated areas. In particular, increased organic and nutrient loading to sediments (as evidenced by an upriver increase in extractable ammonia and sediment organic matter content) would favor a higher sediment microbial oxygen demand and decrease pore water oxygen tensions in and around the root zone of SAV. This potential stress, in addition to the already demonstrated light stress, may in part explain the high summer mortalities of eelgrass transplants in upriver areas such as Clay Bank.

Continuing studies of plant - sediment relations will focus on the sources and fates of organic matter and nutrients in these shoal environments and the specific processes of organic matter mineralization, nitrogen transformation and sediment oxygen distribution and dynamics at both vegetated and non-vegetated sites. These studies are closely coupled with more general studies of nutrient cycling in aquatic environments (see Program IX).

Field and Laboratory Experimental Studies of Environmental Regulation and Controls on Eelgrass Photosynthesis and Growth. Contributions to this program area were also provided through the studies of a visiting scientist, Dr. Jens Borum from the University of Copenhagen. In collaboration with VIMS scientists, his studies were completed during the fall of 1986 on the relationship between grazing intensity and fouling of eelgrass leaves by epiphytes. Preliminary analyses of these data indicate a direct, density dependent effect, and suggest grazers on epiphytes act to control excessive fouling and its negative effects on plant photosynthesis and growth.

Ecological Modelling and Digital Simulation Analysis of Eelgrass Photosynthesis, Growth and Long-term Community Survival. This is a continuing effort, initiated in 1983, that evolves as new data and information are made available to guide model revisions. The results of simulation analysis with the present model version have been used to direct current research activities and generate new hypotheses relating eelgrass growth-survival and specific environmental variables. Further revision of the model awaits analysis of our lower York River monitoring data and the completion of experimental, microcosm studies. However, the results to date suggest that the model can be successfully applied as a tool to establish criteria for resource management. Model revision and testing

along these lines should be accomplished within the current fiscal year.

The Value of Shallow Water Habitats for Recruiting Blue Crab Populations. In comparison to marsh creek habitats, SAV beds contained up to 90 times more juvenile crabs, indicating that these habitats are either being actively selected by recruiting crabs or recruits are experiencing greater differential mortality in marshes. The former possibility has been investigated by both laboratory and field experimentation. In both cases megalopae occurred in greater abundances in *Zostera marina* substrates than in other substrates offered (i.e. marsh mud, bare sand, live oysters, oyster shell, or artificial seagrass simulations). These results strongly suggest that megalopae are able to actively select substrates in which to settle. Our current research is aimed at understanding the mechanisms whereby settling megalopae are able to discriminate between various habitats. The latter possibility (differential predation) may be supported by the fact that the first three juvenile stage crabs are almost never present in marsh samples, and those that are, occur later in the recruitment period when temperatures begin to drop and predators leave the creeks. Larger juvenile stages are found in marsh creeks, possibly indicating that some degree of refuge in larger body size has been attained by these crabs. The question of differential predation on juveniles and larvae will be preliminarily investigated in the fall of 1987 and more detailed experiments are planned for the fall of 1988.

Our work on blue crab recruitment also focuses on the megalopal stage. Whereas it was previously thought that recruitment into nursery habitats occurred primarily in the flora of juvenile crabs, our research now indicates that the megalops may be the most important life history stage in the recruitment process. Laboratory studies have indicated that magnetic micro-wire tags injected into the backfin muscle can permanently mark crabs as small as 20mm wide with virtually no effect on crab mortality.

Subsequent to the laboratory experiment, a 65 day mark-recapture study was conducted on a blue crab population residing in a tidal marsh creek.

Population turnover exceeded 65 days and population size increased by 1.7% per day, from 626 crabs at the onset of the study to 1,428 crabs on day 65. Data suggest that the population in the creek may be comprised of both a resident and a transient component. A similar study was attempted in a seagrass bed during the early summer of 1987 with inconclusive results.

Population turnover within an area was extremely rapid (on the order of 8 hours in one instance), and therefore attempts to recapture marked individuals did not yield the number of returns necessary to conduct the mathematical calculations for the population dynamic model we were using. We hope to further address the issue of relative habitat value for blue crab populations by conducting mark-recapture studies in more isolated grassbeds of a smaller size than those examined to date. Thereby, we will be able to collect virtually all the crabs residing in a single patch of vegetation and examine the dynamics of the entire population.

Goodwin Islands. Research efforts on the Goodwin Islands during 1986-1987 were concentrated on the effects of fire (June 1986) on a high marsh area. Three sampling efforts were made in July and early October to determine the natural recovery processes. Random one quarter meter quadrats were harvested in the burned and unburned areas of the marsh. The unburned clipped plots showed a four-fold increase of vegetative growth between the July and October harvests. Samples taken in the burned area yielded a nine-fold increase in aboveground growth in the same time period. The large measure of growth in the burned area could possibly be the result of reduced shading caused by the burn-off and increased nutrient input of ash left after the fire. Similar harvest samplings will be monitored for a number of years in the future in order to document the effects of fire on a long-term basis in a mesohaline marsh.

Efforts to monitor long-term changes in the physical and biological structure of the islands continued in 1986-1987. Selected aerial photographs of the shoreline were taken in a continuing effort to document the erosion processes working on the islands. Permanent transects were established in the marsh-upland ecotone with the intent of

documenting changes in the composition of this community through time.

The effort to compile a history of the islands, which was initiated last year, has not moved forward a great deal. Some additional materials have been obtained, but analysis and distillation of the material requires more time. Interest in the analysis of this information remains high, particularly because of the historical concern of environmental groups with the islands' development.

Widgeon Grass Reproductive Study. A study focusing on flowering and seed production of widgeon grass (*Ruppia maritima*) began in the spring of 1987 and continued throughout the growing season. Two sampling sites near the mouth of the York River were periodically sampled, one in a tidal, shallow, sandy bottom area at Sandy Point near the Guinea Marshes of Gloucester County, and one in a non-tidal marsh pond on Goodwin Islands in York County. Other sites in the York River and Mobjack Bay were sampled less frequently during the growing season.

Ruppia populations have recently expanded and colonized previously unvegetated shallow bottoms in certain areas of the mid- and lower- Chesapeake Bay. The results of this study should provide a better understanding of the reproductive cycle of this important species.

The study will continue in 1987-1988 with the expansion of additional sampling sites. Preliminary data has shown that flowering begins earlier in the non-tidal ponds than in the tidal sand flats. However, as evaporation increases in the salt ponds during the summer months, plants deteriorate rapidly because of increased temperatures and salinity. Algal epiphytic growth is also much more prevalent on the vegetation in the ponds as the season progresses. *Ruppia* in the tidal habitat were much less inhibited by epiphytic algae.

Program VI. Study diseases of marine and estuarine organisms.

Shellfish. The life cycles of the oyster pathogens *Haplosporidium nelsoni* (MSX) and *H. costale* (SSO) continue under investigation. Unfortunately, no SSO spores were recovered during 1986 and spore feeding experiments using possible intermediate hosts could not be continued. Emphasis was shifted to purifying MSX plasmodia from oyster hemolymph and preparing an antibody to MSX. Difficulty was encountered in separating oyster hemocytes and MSX plasmodia because of the great size range of plasmodia and the clumping tendency of hemocytes. Affinity chromatography is being attempted to remove the hemocytes.

A comparison was made between MSX diagnostic methods of paraffin histology and hemolymph analysis, using monthly samples from May through December. Hemolymph analysis detected over 90% of the systemic infections diagnosed by histology and could be accomplished in one day, compared to three days for histology.

Mobjack Bay oysters, potentially somewhat resistant to MSX, were spawned in the VIMS oyster hatchery and set on shell in August. The spat are presently being monitored for survival in an MSX endemic area in the lower York River.

Acquired Immunity in Oysters. Two parasitic pathogens, *Perkinsus marinus* (Dermo) and *Haplosporidium nelsoni* (MSX), continually threaten oysters in Virginia. The purpose of this study is to determine the feasibility of inducing acquired immunity to the pathogen *Perkinsus marinus* in American oysters *Crassostrea virginica*. This project is supported in part by the Virginia Sea Grant Program. If it is proven that disease resistance can be acquired by immunological means, oyster spat (juvenile oysters) can be protected against disease by immunization before they are transplanted into oyster beds. This would eliminate unnecessary and unpredictable losses to disease in the shellfish industry. Experiments are underway to evaluate the efficacy of immunization with heat-killed *Perkinsus marinus*.

Currently, two groups of oysters have been immunized twice with heat-killed *P. marinus* zoospores (0.9 x 107 spores/oyster). Humoral responses (lysozyme activity) and the capability to recognize and adhere inert foreign particles (fluorescent beads) or the pathogen *P. marinus* in control and immunized oysters are being compared.

Preliminary results indicated that the lysozyme activity in control and immunized oysters

are similar. The measurements of foreign particle and parasite adherence are being completed. Oysters in the immunized group will be immunized one more time. To test the acquired resistance of immunized oysters to the parasite *P. marinus* control and immunized oysters will be challenged with virulent *P. marinus* zoospores.

Research was also initiated in February 1987 to obtain and establish baseline information on humoral activity (lysozyme activity) in oysters. Studies are now underway to determine whether hemolymph lysozyme activity in oysters is associated with seasonal changes in water temperature and salinity, with nutritional and physiological status of the oysters, or with infection of the diseases *P. marinus* or MSX. Initial results reveal that it is related to the water temperature (there is a tendency for lowering lysozyme level with the rise of water temperature) and exhibits a great variation between individual oysters. It also appears that it may be associated with disease infection: It was found to decrease in oysters infected with *P. marinus*, but to increase in those infected with MSX. It may also be related to the oyster reproductive cycle. If oysters were maintained in an environment of constant water temperature, hemolymph lysozyme activity increased when they reached their reproductive cycle.

Oyster Hemocyte Activities. A research project in collaboration with Dr. William Fisher of The Horn Point Environmental Laboratory was initiated in June 1987. The objectives of this study are: 1) to compare the defense mechanisms in terms of ability of hemocytes to adhere fluorescent beads and the oyster pathogen *P. marinus* for different oyster subpopulations (oysters from Mobjack Bay disease-resistant oyster stock, Pocomoke Sound, and upriver of James River); and 2) to seek whether defense factors related to the disease resistance thus provide information for stock selection for breeding based on resistance. Comparison has been made of the hemocyte activities of two subpopulations, oysters from Pocomoke Sound with a history of MSX infection, and oysters from the James River where they are protected from disease by low salinity. Preliminary results indicate that hemocytes from the James River were not as able to adhere fluorescent beads as Pocomoke Sound oysters at all temperatures, and very few parasites were found adhered to hemocytes from both subpopulations.

Program VII. Develop and perfect methods and techniques for economical culture of marine and estuarine organisms.

Oyster Culture. The oyster industry of Virginia has shown a drastic decline over the past thirty years. A factor contributing to this decline is a chronic shortage of natural oyster seed. Hatchery-reared seed appears to offer one avenue of relieving this situation. The West Coast oyster industry has successfully used hatchery-reared oysters in lieu of natural seed over the past decade. In order to eliminate the high cost of transport and handling of oyster shell cultch, the technique of remote setting is used. The oyster larvae are grown in the hatchery until just before metamorphosis or setting, drained onto a fine screen, and transported cool and moist to the oyster planting area where they are placed in a tank of seawater containing cultch and allowed to set.

Although this technique has been used successfully on the Japanese oyster *Crassostrea gigas,* it has never been thoroughly tested on the eastern oyster *Crassostrea virginica.* Research on this technique was initiated at VIMS in 1985.

In 1986 conversion of a building into a pilot-scale oyster hatchery was completed. Local oysters and some northern imports were conditioned during the winter and induced to spawn earlier than their normal spawning period. When natural ripening started in the Bay, selected stocks of oysters were collected, some for immediate spawning and some held in chilled seawater until they were needed. Oysters were spawned from mid-February through the summer. Over 100 million eyed larvae were produced by mid-summer. Almost all of these were distributed to cooperating oyster growers for remote setting. Some were set for use in field grow out and predation experiments. Selected oyster stocks from disease impacted areas have been spawned and the offspring are being tested for disease resistance. Oysters

with traits such as fast growth will also be spawned in an attempt to develop a genetically improved line.

In 1987 the brood stock holding room was enlarged and additional water treatment was added. An area was dedicated to unicellular algal culture. The culture facility using commercial growing methods has managed to produce a prodigious quantity of algal food for use in the larval culture. With these additions, eyed larval production was increased to 400 million eyed larvae by mid-summer.

Information on remote setting techniques has been disseminated to oyster growers through bulletins and through the news media. Two portable self-contained setting tanks have been constructed and are being used to demonstrate remote setting. Individuals who have expressed an interest in testing this method have received eyed larvae and have had the procedures demonstrated at their site.

Besides a number of small demonstrations (50 bushel size), a cooperative experiment has been established with two growers to run a pilot scale 2,000 bushel planting of hatchery-reared remotely set oysters. This will help optimize the methods and point up problems.

Despite the fact that oyster seed has been replanted since colonial times, little is known about the causes of mortality of seed oysters. Field experiments using selected hatchery seed sizes are underway to establish the best size to plant and to develop some insight into the best handling methods for seed of various sizes. Predators and competitors are being identified and some experiments are being carried out to investigate ways of controlling or excluding these species.

Hard Clam Farming. The Wachapreague Laboratory continues its commitment to the development of *Mercenaria mercenaria* culture. The short course on farming clams was again offered this spring. Participants came from New Jersey, Maryland, Virginia, North Carolina, one from Taiwan, and one from mainland China. Over 160 have taken the course since 1974. In addition to those who registered for the course, several hundred have visited this facility. They came from almost every coastal state and 3 foreign countries.

Some predation and biological predator control experiments continue both in the laboratory and in the field.

Pilot-scale hatchery, nursery and grow out of clams continue for both demonstration and experimental purposes.

Metabolism of Dietary Fatty Acids in Oysters. This research was initiated in November 1985 and was sponsored by the National Science Foundation. The goal of this proposed research is to study the metabolism of dietary fatty acids in oysters, particularly the extent of desaturation and elongation of dietary fatty acids to omega-3 polyunsaturated fatty acids (PUFA). Omega-3 PUFA have been demonstrated to be beneficial to human health. Also the effects of temperature and other dietary components on the processes of desaturating and elongating of dietary fatty acids are being investigated.

Studies have been performed to determine whether oysters can biosynthesize PUFA by desaturating and elongating dietary fatty acids (e.g. palmitic (C16:0), linolenic (C18:3W3) and linolenic (C18:2W6) acids). Results indicate that elongation of palmitic acid to stearic acid (C18:0) occurred. Similarly, oysters can convert ^{14}C18:3W3 to ^{14}C20:3W3 and ^{14}C18:2W6 to ^{14}C20:2W6 and ^{14}C22:2W6. No desaturation of ^{14}C-labeled dietary fatty acids was observed. The processes of elongation are very slow. It takes 48 to 96 hours to elongate 1% to 5% of these dietary fatty acids to longer carbon chains (2 or 4 carbons longer). Change of water temperature does not affect the elongation process.

Experiments were also carried out to examine the change in fatty acid composition of oysters fed algae which are deficient either in eicosapentaenoic (20:5W3) and docosahexaenoic (22:6W3) acids (*Dunaliella tertiolecta*) or docosahexaenoic acid (*Tetraselmis suecica*). Results demonstrate that oysters are able to accumulate and conserve omega-3 fatty acids (20:5W3 and 22:6W3) in their neutral and polar lipids for a long period (6-8 weeks), suggesting that the inclusion of oysters in a diet could be beneficial. There was some fluctuation of total lipid content in oysters, but dramatic changes were not observed even in oysters starved for 6-8 weeks. Weight percent of 20:5W3 and 22:6W3 are correlated to the total lipid of the oysters. High weight

percentage of 18:3W3 in the algal diet (*D. tertiolecta*) is not reflected in the neutral lipid of the oysters. The dietary linolenic acid (C18:3W3) was probably being utilized for energy in oysters through catabolism. Both ^{14}C18:3W3 and ^{14}C18:2W6 were found to be degraded to ^{14}C16:0 (palmitic acid) by β-oxidation.

Cryopreservation of Bivalve Gametes and Larvae. A project is continuing to determine if cryopreservation of gametes and/or larvae of oysters and clams can be accomplished. In experiments where larvae are frozen and cooled at controlled rates and immediately thawed, virtually all the larvae survive and continue to develop to later stages. All the larvae which have been stored in liquid nitrogen are actively motile after thawing, but the larvae do not continue normal development. This developmental arrest appears to be a toxic side-effect of the cryopreservative and this problem should be overcome in the near future. Similar experiments on gametes of oysters and clams have not resulted in the recovery of sperm or eggs that yield viable bivalve larvae. Work is continuing on these problems. It is anticipated that viable, frozen larvae will be successfully prepared by the end of 1987.

Oyster Cell Culture. The goal of this project is to obtain continuously dividing oyster cells cultured in vitro. These cultures would be useful for evaluating the role of human disease viruses and other infectious agents in oysters, developing genetic engineering strategies for oysters, and continuing basic biochemical and physiological research on oysters. Techniques have been developed that allow the initiation of contaminant-free oyster cell cultures and permit confirmation of the cultures by biochemical and morphological criteria. Since cell division appears to be limited in cultures that have been examined to date, experiments designed to detect growth-promoting substances have been undertaken. Several compounds which are known to promote growth in mammalian cells have not had the same effect in oyster cells; however, extracts prepared from oyster larvae promote oyster cell growth in vitro. Experiments are planned to fractionate and identify the growth promoting factor(s) in the larval extracts, and to examine the long-term effect of supplementing cell cultures with the extract and purified fractions.

Program VIII. Determine the fate and effect of toxic chemicals in the Chesapeake Bay system.

Polynuclear Aromatic Hydrocarbons (PAH).

PAH Metabolites. Several years of chemical research in the Chesapeake Bay and its subestuaries has identified more than 200 organic substances that are present in sediments, many of them being polynuclear aromatic hydrocarbons (PAH). Some of these compounds have been identified as mutagens and carcinogens, a fact that is also indicated, but not proven, by the pathology of fish living in areas of high PAH pollution. To arrive at a positive correlation between PAH pollution and fish pathology, it is necessary to understand the biochemical reactions involved in the toxicological processes in great detail, particularly as it involves the metabolism of the pollutants.

Research on these problems progresses in two directions, one emphasizing separation aspects, the other identification of structure. The former is required because of the complexity of biological systems. While it never will be possible to separate completely the very large number of PAH metabolites that result from the biochemical processes, sufficient resolution has been obtained using high performance liquid chromatography (HPLC) to demonstrate the bioavailability and biotransformation of PAH and possibly indicate the presence of inter- as well as intra-species differences in metabolite profiles.

The second aspect, structural identification, is required to determine the components that make up the aforementioned metabolite profiles. It is based on a combination of HPLC and mass spectrometry, using a thermospray interface between the two instruments. "Thermospray" is a method of generating a beam of micron-size liquid droplets submerged in a vapor that allows the extraction of ions from the liquid. Solvent flows of up to 1.5 ml/min can be accommodated. When used for glucuronide conjugates of PAH metabolites, which is a form of metabolites commonly generated in fish, this interface allowed the detec-

tion of mass spectra which contained negative quasimolecular ions, an accomplishment that was not possible with direct liquid injection (DLI) discussed in last year's report. Negative quasimolecular ions were also found in the mass spectra of metabolites of benzo(a)pyrene (B(a)P), a PAH, including hydroxy B(a)Ps, B(a)P dihydrodiols, a B(a)P tetrahydrotriol and several B(a)P tetrahydrotetrols. Positive spectra were characterized by the presence of adduct ions, formed by the association of benzo(a)pyrene metabolites and their conjugates with ammonium ions (NH4+). The information content of the spectra is higher than previously obtained when the DLI interface was used. Combined with the less rigorous operating conditions of the thermospray compared with DLI, this will be important as the identification of unknown metabolites is undertaken.

Effect of Sunlight on PAH Toxicity to Fish. Sunlight has been shown in other studies to increase the acute toxicity of specific PAH to fish. In experiments at VIMS, cataracts have been produced in fish in one experiment but not others. One major difference among the various experiments was the presence or absence of sunlight. A preliminary experiment was designed with sublethal concentrations of PAH-contaminated sediment compared to non-contaminated sediment. Fish were exposed to both sediment types in the absence of sunlight (Lab,Lab), after exposure of sediment to the sun (Sun,Lab), and in direct sunlight (Sun,Sun). There were no gross effects produced such as body lesions, fin erosion, or dose-related mortality; no cataracts were observed during daily observations. Eyes were preserved for future histological examination for cataract precursor conditions when appropriate equipment and personnel become available. While the doses were low and perhaps below the threshold for overt cataract formation, superoxide dismutase (SOD) activity in the eyes was affected at the doses tested; all fish exposed to PAH-contaminated sediment had significantly lower ocular SOD than those exposed to control sediment. There was also a trend for increasing ocular SOD based on degree of sunlight exposure (Lab,Lab Sun,Lab Sun,Sun). A PAH effect was also demonstrated by the presence of PAH metabolites in bile samples of exposed fish indicating that the fish did take up PAH.

Mixed Function Oxygenases. A project has been designed to examine the relationships among temperature, salinity and the mixed function oxygenase known as aryl hydrocarbon hydroxylase (AHH). In parallel, the effect of environmental factors on the enzyme superoxide dismutase (SOD) will be examined. While not a mixed function oxygenase, SOD may play an important role in an organism's ability to adapt to the presence of toxic chemicals.

Polynuclear Aromatic Hydrocarbons Monitoring in Estuaries Utilizing Oysters and Brackish Water Clams. Over the last three years this program has allowed us to establish that oysters and *Rangia* can successfully be used to monitor PAH contamination along salinity gradients in estuaries. The results of the surveys have: 1) established a baseline by which changes in future inputs can be assessed; 2) shown that river systems differ in contamination levels; 3) shown that different sources exist within river systems for compounds of both anthropogenic and natural origin; and 4) provided an estimate of yearly variability within systems.

We suggest that the stations in the James and York rivers be resurveyed every 2-3 years to gain more knowledge of natural variations and to assess conditions with time. If spills occur, this background data should be extremely valuable in establishing the geographic extent of effects.

Toxicology and Pathobiology.

Acute Toxicity of Tributyltin to Oyster Larvae. The preliminary effort initiated last year to examine the possible effects of TBT on oyster larvae has been expanded with improvements in an exposure system for flow through toxicity tests with bivalve larvae previously developed for work with chlorine. Results of several tests with oyster larvae in this system indicate that the LC50 for oyster larvae between the late straight-hinge stage and the eyed veliger stage is 1-2 μg/l. Depressed growth was observed at concentrations of TBT as low as 0.2 μg/l, the lowest concentration tested. Additional tests are planned for measuring growth at concentrations down to 0.006 μg/l.

The same test system was used to evaluate the ability of eyed veliger larvae of oysters to set and metamorphose. Total 4-day attachment was

unaffected by doses as high as 5 μg/l, but the time to first attachment was increased at doses as low as 0.3 mg/l. Metamorphosis of larvae exposed to a dose of 0.1 μg/l was comparable to that for control animals, and decreased to zero at doses of 1.1 μg/l and above. Further work is necessary during this critical life history stage to confirm and extend these results.

Laboratory studies have also been conducted to determine the bioconcentration factors for TBT from solution by oysters and hard clams. These investigations have shown similar bioconcentration factors of about 40,000 (based on dry weight) for the two species. Loss or depuration rates were slow.

The effects of TBT exposure on gamete production and sex ratios of adult oysters were also studied in the laboratory. Exposure to TBT did not produce dose related changes in gender over 14 weeks and there was no effect on TBT exposure on maturity or fertilizability of gametes.

VIMS scientists have testified at three separate Congressional TBT hearings. TBT testimony has also been presented at state hearings in Virginia, Maryland and Alaska. Advice on drafting TBT control laws has been rendered to Oregon, California, Washington, New York and Massachusetts.

A Survey of Potential Problems Related To Toxic Organic Chemical Contamination of Aquatic Environments.

Toxicity of Natural Waters to Bivalve Larvae. Chemical analyses of water samples are of necessity geared to detect and quantify specific compounds known or thought to be present. As a result, the chemical observations may not adequately reflect possible toxic impacts. Further, most toxicity tests examine the effects of single compounds on a test species, and thus do not take into account the interactive effects even for an array of toxic chemicals known to be present. While there are models for using single-species toxicity test data to estimate the effect of mixtures, these models are largely untested.

A more direct approach is to test receiving water samples for toxicity to one or more species. In a preliminary step to implementing a full scale program, a sample of water from near a marina in Hampton Creek, Virginia has been tested for toxicity to oyster larvae. This sample proved to be quite toxic. When expressed in terms of the measured quantity of TBT in this sample, it is apparent that other chemicals contribute to the observed toxicity of this water sample. Further research in this area is planned for the coming year involving both bivalve larvae and mysid shrimp.

Immunotoxicology. The objectives of this program have been: 1) to develop a chemiluminescence (CL) assay to measure fish cellular immune activity; 2) to determine the effects of prolonged exposure to PAH on the cellular immune system; 3) to determine the immunological effects of exposure to toxic levels of tributyltin (TBT) on the immune system; and 4) to assess the usefulness of the CL assay as a monitor of exposure to toxicants.

Measurement of functional elements of the immune system in fish can provide information about the degree of exposure to environmental stress. The CL assay technique is being developed for possible use as a monitor of the health of fish in the Chesapeake Bay. Preliminary data using this assay technique indicate that chronic exposure to PAH-contaminated sediments in the Elizabeth River depresses the CL response of fish cellular immune systems. This effect has been observed in fish exposed to PAH both in the wild and in the laboratory. In addition, initial studies evaluating the toxicity of tributyltin on certain aspects of the fish cellular immune system indicate a significant decrease in the CL response after exposure of the cells to TBT.

These preliminary findings indicate that the CL assay has potential value as a measure of overall fish health and the biological effects of exposure to toxicants. Future activities will evaluate the response in other species of fish to various chemical pollutants.

Pathobiology. The objective of our pathology research is to provide important facts relative to the effects of toxicants on health of individual finfish and their populations in Virginia's tidal waters, and their implications to environmental and human health.

The Elizabeth River is one of the most heavily contaminated subestuaries in the Chesapeake system. Toxicants of many types exist, often at very high levels. We have focused upon this river to

study effects of toxicants on the resident and transient biota. Collections involving over 75,000 individuals of several finfish species have been made. Comparison collections came from the less-contaminated nearby Nansemond River, York River and Mobjack Bay.

Finfish from the Elizabeth River regularly exhibit several types of externally-visible lesions recognized as signs of contaminant-related stress and disease. Included are cataracts of eye lenses, fin rot, ulcerations and hyperaemia. Animals from the Nansemond River have shown none or far fewer. These externally-visible lesions are dramatic and readily quantifiable signs of toxic distress, and research is underway to determine if they can be used as early-warning signs of contamination for environmental bioassay and monitoring. Fin rot and ulcerations seem to be general responses to toxic exposure. Cataracts may be specific to PAH.

Histological examinations have been focused on the gills, liver and kidneys, all likely target organs, and important in the uptake, transfer and handling or clean-up of toxicants. Work has focused on five fishes, two endemic bottom-dwellers, hogchokers and oyster toadfish, and three transient pelagics, spot, Atlantic croaker and weakfish, all important commercially and recreationally. Numerous lesions and abnormalities have been found in these fishes, and much remains to be learned from further study and future laboratory research.

Program IX. Study nutrient cycling processes and controls in riverine, estuarine and coastal marine environments.

Is Phosphorus Removal An Efficient/Effective Chesapeake Bay Management Practice? This project continued in its second year to determine which nutrient, nitrogen (N) or phosphorus (P), limits or controls phytoplankton primary production on a seasonal basis in the lower Chesapeake Bay. Managers are generally agreed that 1) nutrient enrichment is a major cause for water quality degradation of the Chesapeake Bay and its tributaries; 2) reduction in nitrogen or phosphorus, or both, will be necessary to improve Bay water quality; and 3) a phosphate detergent ban is a significant interim step toward reducing nutrient inputs into the Bay.

Nutrient enrichment is thought to promote the deterioration of receiving waters by stimulating algal growth. Excessive algal biomass contributes, through its subsequent death and decomposition, to low oxygen levels in deeper waters. The paradigm that algal production is typically phosphorus-limited in fresh waters and nitrogen-limited in marine waters does not take into account estuaries where one might assume that some intermediate or non-steady state condition should exist. The present study, together with a similar project carried out by colleagues in Maryland at the Benedict Estuarine Research Laboratory and the Chesapeake Biological Laboratory (BERL/CBL) at lower salinities, seeks to develop an understanding of the temporal and spatial extent to which a given nutrient limits or controls algal production in Chesapeake Bay.

This knowledge is essential in order to implement the most efficient management practices related to reduction of nutrient loading. For example, since results show that phosphorus controls algal productivity in the saline portions of the Bay mainly in the winter time, phosphorus removal in both the fresh and salt portions of the Bay system on a year-round basis may be an unnecessary expense.

A site in the lower York River, where salinity varied from 12 to 24.5 ppt during an 18 month period, indicated phosphorus control of phytoplankton production from December through April and nitrogen control during the rest of the year. These results were similar to those from the Maryland site where the salinity varied between 3.2 and 10.5 ppt.

Using these combined data sets and the assumed conditions that freshwater phytoplankton are always P limited and oceanic phytoplankton (i.e. at about 36 ppt) are always N limited, an appropriate scenario is as follows: phosphorus limitation displaces nitrogen limitation down the estuary (i.e. Chesapeake Bay tributaries) during the fall and winter to salinities as high as 25 ppt (York River, February 1987) and in turn is displaced by nitrogen limitation up the estuary in late spring and summer to salinities below 3.8 ppt (Patuxent

River, May 1984). A possible explanation of this change of position of P to N limitation can be related to variations in the relative inputs of N and P to the estuary as follows: the seasonal distribution of dissolved phosphate-P in estuaries shows a seasonal cycle with the maximum concentrations in summer and the minimum in winter. Inputs from point sources such as sewage can be expected to be relatively invariant seasonally. A large input of non-point source nitrate-N from wintertime runoff increases the nitrogen to phosphorus ratio so that there is phosphate limitation during the winter and nitrogen limitation during the summer in estuaries.

Understanding Nitrogen Cycling Processes and Controls By Using Nitrogen-15 Stable Isotopes. This is a continuing program initiated in 1984 to develop reliable techniques to study microbially mediated nitrogen transformations in aquatic environments using the stable nitrogen isotope, N-15, and to determine (using N-15 as a tracer) the rates of nitrification in the upper James River as a function of downstream distance from major sources (Sewage Treatment Plants), temperature and river flow.

Nutrient Cycling. Nitrification or the oxidation of ammonia by a group of lithotrophic bacteria has been a topic of concern in the upper James River, mainly because this process can contribute to the reduction of dissolved oxygen to unsatisfactory levels. Microbiologists continued research on the development and verification of techniques to measure nitrification of sewage treatment plant-derived ammonia. During this period, the first nitrification rate data for the upper James River was calculated using a N-15 stable isotope tracer method. The data indicated nitrification did occur in the river and is an important oxygen consuming process. Field studies are continuing to evaluate the effect of season and precipitation on this process. The analytical methods and protocols developed for this study are expected to find application as powerful research tools for the study of nitrogen cycling in estuarine systems as well as the low dissolved oxygen issue.

Isotopic Determination of Nitrogen Sources and Processing in Chesapeake Bay. This is a new project initiated in January 1987 with funding provided by National Oceanic and Atmospheric Administration (NOAA) and Sea Grant. It is a collaborative effort between scientists at VIMS and the University of Virginia. Phase I of the study (a largely descriptive effort) will be completed in December 1988. The overall objective of the study is to determine the origins and fates of nitrogen entering the Bay's tributaries and mainstem, and the processes of nitrogen transformation between its various inorganic and organic states that potentially result in eutrophic plant growth. Our first year efforts will focus on mapping the stable isotopic distributions in the York River estuary and determining rates of nitrification, denitrification and ammonia remineralization in waters and sediments collected from sites having specific land-use characteristics--agricultural, rural development, sewage impacted, and natural. Concurrent with these field and laboratory studies, will be the development of a preliminary model of nitrogen input, internal processing and isotopic fractionation, and ouput for the York River basin.

Program X. Evaluate factors leading to, and the consequences of nutrient enrichment.

Effects of Bottom Sediments on Water Quality. Recent mathematical modelling studies done for the Chesapeake Bay Program confirm that processes occurring in the sediments and the exchange of materials between the sediments and the overlying waters are very important factors regulating water quality conditions.

Current research efforts are intended to improve our understanding of the factors controlling the release of nutrients from the sediments. Sediment-water nutrient and oxygen exchange cannot be measured everywhere at all times. A pressing research need is for conceptual models that can predict sediment-water exchanges at locations in which and at a time when observations are lacking. Before predictions can be accepted, the models must be tested against existing observations.

Presently, research is focusing on developing the data necessary to formulate and validate sediment-water exchange models. Laboratory simulations of sediment-water processes in tidal freshwater systems are being conducted. During

the simulations, observations of sediment and water biogeochemical properties are collected and sediment-water exchanges of nutrients and oxygen are measured. Simulations are conducted with different nutrient concentrations and pH in the overlying water so that an extensive data base exists for testing the models.

Concurrent with the simulations, a predictive model of sediment-water oxygen and nitrogen exchange is being developed. The model provides guidance as to what parameters need to be measured in the laboratory while the experiments indicate potential shortcomings in the model formulation and performance.

Program XI. Understand the dynamics of benthic boundary layers and associated processes of sediment resuspension, transport and animal-sediment interaction in coastal and estuarine environments.

The overall objective of this program is to determine the dynamics of the benthic boundary layer with respect to sediment resuspension and transport. The underlying goals are: 1) to improve management of dredged materials; 2) to predict and control shoaling in navigable waterways and ports; 3) to predict the accumulation or erosion of different types of sediment; and 4) to anticipate and avoid possible buildup of toxics adsorbed to certain types of sediment.

Research efforts addressing these objectives were accelerated significantly during 1986-1987. A year ago technological advances in measurement tools for investigating sea floor and Bay floor phenomena were reported. Over the past year those tools, which include two highly sophisticated benthic boundary tripods, remote sensing devices such as side scan sonar, acoustic sediment profiling methods and a sediment profiling camera, and an assemblage of associated computer software were refined. VIMS now possesses state-of-the-art capability in this area. Application of these tools to different benthic environments in the Bay and on the inner shelf involving heavy field activity resulted in several important advances in the understanding of bottom processes.

There was a refinement of the geophysical classification of the bottom types in the lower Chesapeake Bay and adjoining estuaries and inner shelf. Tripod deployments on several of the bottom types were made with the intention of documenting the differences in sediment transporting forces. As part of this effort, near-bed currents were measured at two dredged material disposal sites, one in the lower Chesapeake Bay and the other on the upper shoreface of the inner shelf. During two winter storms the inner shelf site was dominated by strong wave-induced oscillatory flow at periods of about 10 s superimposed on wind-induced southeastward currents that exceeded 35-40 cm s^{-1} at 55 cm above the bed. This environment is thus likely to be quite active in terms of bottom sediment resuspension by waves and subsequent entrainment and advection through moderately swift, unidirectional currents associated with a storm.

The estuarine site in contrast was dominated by tidal currents with very little indication of wave-induced motion at the bed except for low amplitude, long-period swell (- 16 s) that appeared to emanate from the Bay entrance. At the time of the highest spring tides, bottom currents 20 cm above the bed attained sustained speeds in excess of 30 cm/s and at 100 cm, more than 45 cm/s. Superimposed on the net flow, a very energetic turbulent component having an rms intensity of about 11% of the mean horizontal current was observed in a series of 10-minute time segments. Pressure variations measured during this "burst-like" turbulent activity were almost nil. It is believed that the turbulence encountered may be a significant contributor to Reynolds stresses acting to entrain fine sediment.

The sharp gradients in bottom types and physical processes are accompanied by dramatic contrasts in the sedimentology, stratigraphy, and faunal activity of the upper part of the sediment column. We documented the recent sediment record from more than 350 sites in the lower Chesapeake Bay and associated tributaries, which range from muddy, tidal-freshwater areas to the sandy Bay-mouth. In low salinity areas sediments were physically structured when sediment accumulation was rapid, but biotic reworking was oc-

casionally important in areas of fluctuating deposition or erosion deposition cycles. Biological mixing predominated in high salinity areas even when areas were characterized by moderate to rapid accumulation and strong tidal currents, but was less important where physical reworking due to oceanic or wind waves was intense. In this study, a posterior allocation of radiographs to subenvironment categories aided in the identification of patterns of variation. Change within subenvironments was gradual and concordant with the estuarine gradient. Cross-estuary gradients in stratigraphy were steep, reflecting rapid changes in biological and physical/geological processes and the interactions of these processes in adjacent subenvironments.

Other developments within the benthic boundary layer program included: 1) a study of the effects of shipping on bed disturbance in the Elizabeth River, revealing that shipping does increase turbidity and redistribution of toxic-bearing cohesive sediments (recommendations for control of these effects were presented); 2) a field data determination of the probability that either energetic high-frequency internal waves or bursting phenomena are important to the resuspension of sediment in the Bay stem plains environment; 3) development of two independent numerical models which predict the effects of boundary layer interactions of combined waves and currents; and 4) field observations of turbid, gravity-driven underflows which demonstrate this mode of diabathic transport over shallow-water beds composed of fine material, and high frequency internal waves that contribute to interfacial friction at the top of such underflows.

Program XII. Describe and understand the circulation of waters in the estuarine and coastal environment.

Circulation Patterns in Hampton Roads. Research efforts during the present year have focused on the complex circulation patterns in the vicinity of Newport News Point. In particular, many days of field study were devoted to monitoring the behavior of fronts. These fronts develop at the early phase of flood tide, move upriver at the speed of several meters per minute, then slow down over a region of steep bottom slope, and eventually dissipate as the flood currents wane. Numerous tracer experiments demonstrated that surface waters are injected through the front to depths of four meters or more in the vicinity of the depth transition.

Two features of the flow field that are essential to frontogenesis are the convergence of the surface currents and the density contrast between the convergent flows. Scientists developed a one-dimensional approach that relates characteristics of the water masses and the geometry to predict the vertical transport through the front and the movement of the front. Field measurements of vertical transport were found to agree with the analytical predictions, and the observed movement of the front was explained satisfactorily with the theory.

Mathematical Modelling of Hampton Roads' Circulation. A state-of-the-art mathematical model has been acquired to aid scientists in their studies of circulation patterns. Salinity differences, topographic patterns on the bottom, the meandering course of the river channel, and other factors all contribute to make circulation patterns complex. Consequently, it is necessary in some instances to use models that simulate the flows in all three spatial dimensions as well as time variations. One such model, which has been used in Maryland and also will be applied to the main stem of Chesapeake Bay, was developed by Dr. Peter Sheng, now of the University of Florida. Dr. Sheng and his staff are working with VIMS' scientists in the application of the model to the James River estuary. To date the model has been calibrated only to the point where the flows are roughly simulated. In the coming years, modelers will refine and improve this calibration. Then it will be possible to examine aspects of the flow in much greater detail than heretofore possible. Current meters are expensive and deployments of the meters require large amounts of staff and vessel support for maintenance. By examination of model simulations, it should be possible to locate current meters to corroborate model simulations and to do this in an optimal fashion. Field efforts and model studies should go hand-in-hand, each providing useful information to the other.

Program XIII. Develop a better understanding of shoreface, surf zone, and beach processes.

The objective of the program is to develop a better understanding of shoreface, surf zone, and beach processes in order to provide more effective measures to mitigate shore erosion. As in previous years, effort has been shared between: 1) applied research and associated advisory activity aimed at dealing with the immediate and day-to-day problems of erosion along the shores of the Commonwealth; and 2) more basic research aimed at providing a deeper understanding of the fundamental mechanisms which operate to cause beach and shoreline changes.

In connection with the applied shoreline research, a formal memorandum of understanding was negotiated between the Virginia Department of Conservation and Historic Resources (DCHR) and the Virginia Institute of Marine Science whereby VIMS scientists continue to conduct applied research and provide advisory services under contract to DCHR.

VIMS responsibilities under the memorandum of understanding include conducting research into innovative low-cost erosion control techniques; providing technical advice to the Public Beach Board and Shoreline Erosion Advisory Service (both of which are units of DCHR); and conducting research on the coastal dynamics and beach stability of shoreline reaches of the Commonwealth of Virginia.

The applied research activities included field demonstrations showing that use of breakwaters for erosion control of estuarine shores is applicable to medium energy situations. In addition, an updated computer model incorporating the effects of refraction, shoaling, diffraction and energy dissipation by the combined effects of bottom friction and wave-current interaction was developed and applied to the coastal reach from Cape Henry to Duck, North Carolina, to predict longshore variations in breaker height, littoral drift, and beach stability.

As reported last year, much of our basic research in previous years focused on the dynamic variability of surf zones and beaches. During 1986-1987 our attention was focused on the shoreface region seaward of the surf zone, since this region serves as a "conduit" for the cross-shore exchange of sand between the continental shelf and the shore.

Our initial analyses of data and published literature show that bidirectional sand transport across the shoreface in the shore-normal dimension is a key factor affecting short- and long-term fluctuations of beach and surf zone sand storage as well as the morphology and stratigraphy of the shoreface. Depending on regional energy regime, the seaward depth limit for active diabathic sediment exchange ranges from 10 m to 30 m.

Simple models which account for shoreface transport and equilibrium development solely in terms of shoaling waves are probably inadequate for most natural situations. Recent literature provides ample evidence that, in addition to waves, near-bottom diabathic flows associated with wind- and tide-generated currents may dominate net sediment flux. Wave-current interactions as well as variations in bed roughness can affect not only the magnitude but also the direction of net transport. Gravity-induced transport of plumes of fine suspended sediment may be important during storms.

In order to predict better the transport of sand shoreward or seaward, a numerical computer model was developed which utilizes the latest theoretical and empirical approaches to model the cross-shore transport of sand under combined wave and current forces.

The research tools described with respect to the benthic boundary layer program have also been heavily utilized in the shoreface program. One of our instrumented, bottom-mounted tripods deployed off Duck, North Carolina, at a depth of 8 m provided time series of pressure, benthic currents, suspended sediment concentrations and bed-level changes prior to and during a typical northeast storm. A strong jet-like southerly-setting current generated by the northeaster was accompanied by downwelling and strong bottom agitation by wind waves. A total bed-level change of over 15 cm was recorded. After a phase of bed erosion, the bed accreted rapidly. Side scan imagery supports the inference that offshore or alongshore migration of quasi-discrete sediment

lobes may have produced the observed pulse-like accretion.

Additional developments within the shoreface program included: 1) analyses of long time series of tidal observations from selected Virginia tide stations utilizing a new analytical procedure (complex demodulation) and showing that shallow-water M4 overtides are time dependent tidal constituents and are temporal modulators (flood or ebb) in basin-inlet systems; 2) analyses of field data from the surf zone at Duck, North Carolina, utilizing analytical techniques recently developed at VIMS showing the group-bound long wave is amplified, released, and reflected in the surf zone; 3) development of a numerical model which predicts patterns of net cross-shore mass transport and sediment flux in the surf zone due to the combined effects of incident waves and long waves; and 4) assessment of erosion rates and nourishment requirements of selected Virginia beaches.

Program XIV. Describe and explain the late Quaternary sedimentology, stratigraphy and geologic evolution of the Chesapeake Bay and coastal waters.

The objectives of this program are to describe and explain the sedimentology and Quaternary geologic evolution of the Chesapeake Bay system and adjacent portions of the continental shelf to learn more about the region's geologic resources, such as heavy minerals, aggregate and shell, and about the long-term sources, sinks, pathways and processes for transportation of sediments and associated contaminants. This program is highly complementary to and interactive with the programs relating to the benthic boundary layer (Program XI) and to the development and utilization of marine resources (Program XV).

A major basic research element of this program in 1986-1987 involved a comparison of the sediment storage efficiencies of Chesapeake Bay and other East Coast estuaries. This study addressed the questions: 1) of the total amount of fluvial sediment supplied to an estuary, how much is stored and how much passes through to the ocean?; 2) how efficient are estuaries in storing sediment? and 3) what factors regulate the storage efficiency?; These questions are of fundamental interest for determining the fate of river borne contaminants and the flux of sediment through the coastal zone. A contributor to this study was Dr. Jae-Kayung Oh from the Department of Oceanography, Inha University, Korea, who spent a one-year sabbatical at VIMS through the visiting scientist program.

From the study it was found that storage efficiency (i.e. ratio of sediment accumulation to river input rate) ranges from 0.7 in the Altamaha River, Georgia, to 7.6 in the Choptank River, Maryland. The northern estuaries have a much greater storage efficiency than the southern estuaries. For example, the Rappahannock and Choptank rivers store an amount equivalent to their total river input in addition to large amounts of sediment supplied from other sources as the sea. The James and Potomac rivers have intermediate storage efficiencies of 1.1.

The southern estuaries accumulate major sediment loads in their marshes and allow partial escape through channels to the sea. Within the range of partially-mixed and well-mixed estuarine systems compared, storage efficiency is greater in estuaries having a high degree of stratification.

It is concluded that storage efficiency of the northern estuaries is regulated by the strength of the estuarine circulation with landward flow through the lower salt layer. Storage is also encouraged by relatively low flushing velocity and high volumetric capacity compared to river inflow. As a result of the moderate to high storage efficiency, most particle-reactive contaminants supplied by rivers are likely to be retained in the northern estuaries and thus the regional impact of contamination on the ocean is minimized.

As in 1985-1986, major efforts this year were devoted to locating, mapping and proving the subaqueous mineral resources of the Commonwealth. The Institute's search for economic heavy minerals, conducted under the sponsorship of and in collaboration with the Virginia Division of Mineral Resources, involved intensive field activity including coring and acoustic surveys off Virginia Beach and off the Eastern Shore. High concentra-

tions of heavy minerals have been located in the upper portion of the sediment column on the flanks of topographic ridges offshore from Smith Island.

In addition, considerable field effort has centered around the search for buried or superficial reserves of fossil oyster shell. Using a combination of acoustic subbottom profiling and vibratory coring, significant fossil shell reserves have been located in at least two locations within the lower Chesapeake Bay.

The extensive seismic subbottom surveys that have been conducted in search of economic reserves of heavy minerals, shells, and sand have also yielded scientific results which provide insights into the geologic history of the Bay. Data from three recent studies converge to demonstrate the transport of sand into Chesapeake Bay from the adjacent shelf. A 100-year sediment budget, distributions of heavy minerals, and seismic-reflection data all point to the Bay-mouth as a gate through which a significant quantity of sand enters the estuarine system.

Construction of a sediment budget that attempts to balance the mass of material deposited during the past century, as determined by bathymetric comparisons, with the quantity of material available from documentable sources (shoreline erosion and fluvial discharge) reveals that 6 to 20 times more sand has been deposited than those sources have provided. Most of this excess deposition occurs in the region dominated by Bay-mouth processes.

Seismic-reflection data indicate that the Bay-mouth sand bodies are part of a thick package of beds that dip into the estuary. This extensive package, more than 10 m thick, began to form several thousand years ago, as sea level approached its present position. Although it has built vertically in response to continued sea-level rise, its primary growth has been by progradation into the estuary.

Factor analysis of heavy mineral assemblages from the Bay and adjacent shelf demonstrates a mixing of populations. Sample composition gradients indicate transport and sources of sediment both in and out of the Bay-mouth. These analyses in the context of the seismic and budget data demonstrate a landward transport vector.

Finally, a late Quaternary sea-level curve was developed based on data from the Eastern Shore of Virginia, and a new depositional model was developed for island and back-barrier sedimentation based on field data from the Virginia Barrier Islands.

Program XV. Conduct investigations related to the development, utilization, and management of resources of significance to the marine environment.

One of the objectives of this research program is the development of management strategies for the conservation and/or development of Virginia's living and non-living marine resources. These resources are affected by activities and other resources that are beyond what is traditionally considered the marine environment. To fulfill effectively the mandate expressed for the Institute, comprehensive studies must be pursued and result in recommendations useful to the management of these marine resources. Inherent in such a research program is the need to evaluate, modify, and develop scientifically, economically, socially, and legally sound resource use strategies for individuals and institutions involving the Commonwealth's living and non-living marine resources.

Legal Evaluation of Virginia's Erosion and Sedimentation Control Program. A legal evaluation of Virginia's erosion and sedimentation control program and a review of State and local compliance with the provisions of that law was completed for the Division of Soil and Water Conservation. Through the use of a questionnaire, a survey of Virginia's Commonwealth, city, and county attorneys was conducted. Analysis of questionnaire results identified lack of manpower, weak penalties, statutory exemptions, and lack of judicial support as significant impediments to enforcement of the current statute. Recommendations to alleviate these impediments included the strengthening of the administrative and enforcement provisions of the statute at the State and local levels.

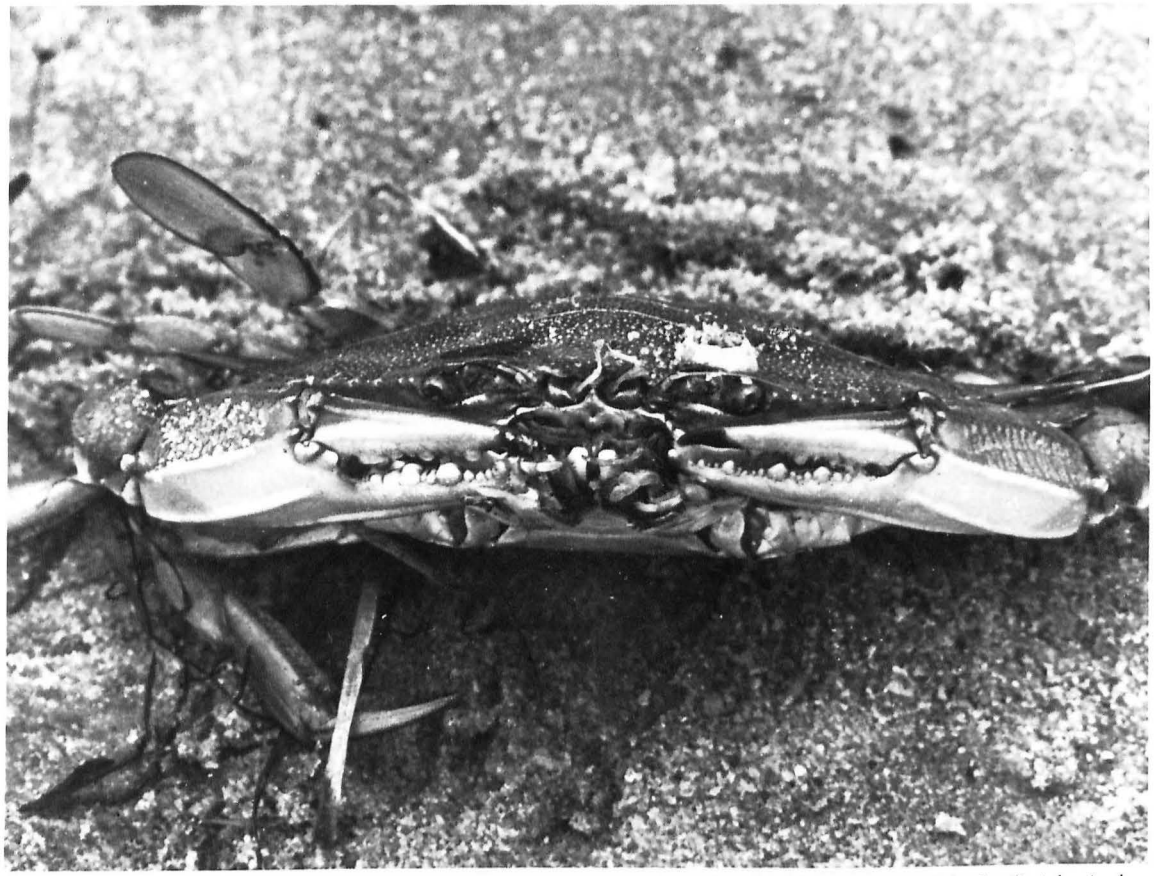
Recommendations for Aquaculture Legislation. Research efforts leading to the development of recommendations for aquaculture legislation continued. Legal, policy, and institutional impediments affecting the development of Virginia's aquaculture industry were identified. Recommendations for removing or mitigating these impediments have been drafted. If successfully implemented, legislative changes should enable the Commonwealth to realize more effectively the economic potential of marine aquaculture and encourage the development of new technologies.

Estuarine Research Reserve System for Virginia. The National Estuarine Research Reserve System is authorized by the federal Coastal Zone Management Act. When completed the system will provide, through a federal-state partnership, a national network of estuarine research reserves representing the various biogeographic regions and estuarine types in the nation. The purpose of the system is to provide opportunities for long-term research, monitoring, education and interpretation. The scientific and educational programs will focus on development of information for improved management of coastal resources.

During the period of this report, VIMS personnel worked with a panel of estuarine scientists from other Virginia universities, federal resource agencies and private conservation organizations to review 113 sites in the Virginia portion of Chesapeake Bay and its tributaries to select up to sixteen sites representing the variety of Virginia's estuarine habitats.

Approval for developing a management plan and an environmental impact assessment for the program will be submitted to the Federal government during 1987-1988.

Monitoring



The Chesapeake Bay blue crab is one of the important commercial species monitored as part of the Institute's stock assessment program.

The Virginia Institute of Marine Science, as the major marine research institution in Virginia, is continually called upon to express opinions and comments on the probable effects of industrial development and other perturbations on our estuarine and coastal waters. This requires extensive background information on the system being impacted, so that one can distinguish "normal" ranges of fluctuations from aberrations caused by man's activities.

Many items have been and are being monitored at VIMS. Entities to be monitored are selected with consideration of the issues of importance; however, virtually all monitored information can be and is used for multiple purposes (i.e., for descriptive background information helpful in basic research, as well as provision of data for advisory services).

Program I. Fisheries

Anadromous Fishes. The major objective of this monitoring program is to maintain a long-term data base on anadromous fishes in order to understand the population dynamics of these species as well as to assist in basic research of individual species. In turn, the data are used in advisory services, basic research, and population dynamics. The anadromous projects, in conjunction with those of other states investigating Alosa and striped bass stocks, contribute to the general

knowledge necessary for evaluation of rational management alternatives, both in Virginia waters and coastal waters of the eastern United States.

The Alosa stocks (American shad, alewife, and blueback herring) and their fisheries in Virginia were evaluated by sampling adult Alosa taken from the commercial catches in the James, York, and Rappahannock rivers during the spring spawning migrations. Individuals of each species were sexed, and lengths and weights recorded. Otoliths and scales were also taken for aging each specimen. Juvenile (young-of-the-year) Alosa were sampled with a specially designed pushnet developed at VIMS. Indices of abundance for juvenile Alosa, derived from catch and effort data, were compared to previous annual indices.

Adult striped bass were collected from commercial fisheries in the York, Rappahannock and Potomac rivers to characterize the composition of catches in gillnets and pound nets by sex, age, length and weight in the spring and fall-winter fisheries.

Juvenile Striped Bass Research. Monitoring of the relative annual abundance of juvenile striped bass (rockfish) in the Virginia nursery areas was continued for the seventh consecutive year and the fourteenth year since 1967. Sampling is conducted during the summer months with a 100 foot beach seine. The 1986 index was the second highest recorded (exceeded only by 1970), continuing a trend of the improving recruitment seen in recent years. This apparent early indication of a possible recovery of the Virginia populations of striped bass is in sharp contrast to the situation in the northern portions of Chesapeake Bay, where the recruitment index continues to lag well behind the historical average.

In addition to the regular survey, considerable supplementary sampling was conducted in a effort to understand better juvenile distribution patterns and the effect of these patterns on survey results. Investigations into environmental influences on growth and survival of first year striped bass are also underway.

Spatfall Monitoring Program. The oyster (*Crassostrea virginica*) spatfall monitoring program, using shell strings as a standard substrate for settlement, recorded a moderate to high level of settlement in all areas with the exception of the James River and the Potomac River. These two rivers, in general, recorded a moderate to low settlement.In addition to spatfall monitoring, surveys of the condition of oyster rocks at selected sites throughout Virginia waters were carried out in the fall of 1986 and the spring of 1987. These indicated that recruitment to the bottom was low in the James River; the highest oyster spat newly settled oyster count recorded in the James River was 116 spat per bushel. By contrast, the seed oyster resources in the upper Piankatank and Great Wicomico rivers were satisfactory to excellent depending upon the rock examined.

Market oyster producing areas affected by increased incidences of disease exhibited mortalities of up to 70%; however, unaffected areas in Pocomoke Sound, the Rappahannock River and the upper James River produced good catches of oysters.

Stock Assessment. The long-term series of routine monthly trawl surveys for fish and blue crabs in the York, James, and Rappahannock rivers has been continued. Previous collection procedures are followed except that all fishes and blue crabs are now measured to make data more amenable to analysis.

Funds acquired from the Chesapeake Bay Stock Assessment Committee are being used to upgrade data management and analysis capabilities. This upgrading should greatly increase abilities to analyze data. Such funds are also being used to plan the extension of routine trawl survey programs into the Chesapeake Bay.

Program II. Plankton

Phytoplankton Monitoring. Phytoplankton monitoring in the lower York River continued with sampling at the United States Coast Guard Reserve Training Center at Yorktown, Virginia. As in the past five years, sampling was confined to two time periods: 1) a high temperature, summer period (September 1986) when the phytoplankton community is composed primarily of small cells ($< 15\ \mu m$) dominated by small flagellates and cyanobacteria; and 2) the spring bloom period (6 March through 6 May 1987) when large diatoms

and dinoflagellates dominate the phytoplankton community.

A primary objective of the phytoplankton monitoring is to elucidate long-term trends in the species composition and/or abundance as related to trends in eutrophication or nutrient enrichment. All cell counts are made using epifluorescent microscopy, and efforts continued during the year to have this methodology incorporated into the Chesapeake Bay phytoplankton monitoring program (see Research, Program III, Innovative Technology and Methodological Development).

In addition to long-term trends in phytoplankton processes, the temporal nature of our sampling scheme (three times per week) also permits us to investigate shorter term phytoplankton dynamics. An investigation of the response of the cyanobacterial community to the tidally induced, fortnightly cycle of water column stratification or destratification which characterizes the lower York River, is one example of how the monitoring program supports the investigation of basic phytoplankton processes. A masters thesis related to this aspect of the monitoring program entitled "The Role of Picoplankton in Phytoplankton Dynamics of a Temperate Coastal Plain Estuary" was completed during the year.

Efforts continue to develop automated counting techniques for natural plankton using computerized image analysis (See Research, Program III, loc. cit.).

Program III. Bacteria (Lower York River)

Seasonal bacterial surveys of the lower York River were continued to determine densities of indicator bacteria, heterotrophic and petroleum-degrading bacteria in the water column and sediments. Selected river sites were also monitored for the human enteric pathogens *Salmonella* sp. and *Yersina* sp. Both these organisms have been recognized as pathogens which can be transmitted through consumption of raw shellfish. These organisms were frequently isolated from the lower York River, but at densities which do not appear to pose a public health threat. Their presence was not predicted on the basis of fecal coliform indicator densities. The lower York River bacteria data base has been made available to NOAA and will be incorporated into a national data base.

Program IV. Parasites and Pathogens

Shellfish Diseases. 1986 was the second year in a row of severe drought in the Chesapeake Bay region and record high salinities were recorded in the Bay during summer. Increased salinity was favorable for both major oyster diseases, *Haplosporidium nelsoni* (MSX disease) and *Perkinsus marinus* (previously called Dermo). James River oysters susceptible to MSX held in trays at VIMS developed the highest prevalence of MSX ever recorded in Virginia. MSX prevalence gradually increased through the summer and reached 80% in early September; peak mortality of 67% per month occurred in late September/early October. By early December 76.6% of the 1,000 oysters in the trays had been killed by MSX. MSX was also abundant in native oysters in Mobjack Bay, an area thought to contain oysters that were somewhat resistant to MSX based on previous studies. Two samples collected in early December had prevalences of 68% and 44% with many heavy infections. Apparently, the intense infection pressure during 1986 overwhelmed even these resistant oysters. MSX was also present in oysters in the lower portion of the James River seed oyster area, the lower Rappahannock River and in the Great Wicomico River.

Perkinsus caused serious oyster mortality during 1986, especially on privately planted grounds. The increased salinity allowed this parasite to move into oysters in the lower James River seed oyster area where, on some beds, it infected over 90% of the oysters. Many private planters transplanted seed oysters from these beds to normally low salinity areas in the Potomac River. In most years *Perkinsus* would not have developed further in these low salinity areas but, because of the prolonged drought, salinity was favorable for development of the parasite and high mortality occurred in the transplanted oysters. Unfortunately, *Perkinsus* is now established in Potomac River tributaries and it may take many

years of normal low salinity to eradicate the parasite.

Program V. Benthic Invertebrates

The objective of this program is to follow the natural population dynamics of the soft bottom invertebrate communities. These community data then give a reference point from which to assess the impacts of man's activities. The natural ecosystem is inherently variable through time and it is only with long-term data that it is possible to accurately separate community changes into component parts, natural or man-induced.

At Deep Muddy Station (10 m), that has been sampled since 1960, the communities continue to change in different ways. At no time in the last 26 years have the communities repeated themselves exactly. Dominant species, in terms of numbers and biomass, continue to change yearly. This year the trend of increasing numbers of higher salinity species has continued. This trend has been evident for the last four years and may reflect the climatic events in the Bay's watershed.

With the increasing concern over low dissolved oxygen around the Bay, a series of stations have been established in the lower Rappahannock and York rivers and in the mainstem of the Bay, from Rappahannock Shoals to Wolf Trap, to evaluate the response of the benthic communities.

Preliminary results indicate that hypoxia (dissolved oxygen of 2.0 mg/1) and anoxia (no oxygen) in the Rappahannock River have eliminated many benthic species from localized areas. Recolonization of these areas will be followed. How seasonal low oxygen affects the resource value of these benthic habitats will also be determined. In the York River, dissolved oxygen fluctuates with neap-spring stratification-destratification of the water column, and benthic communities and not as severely affected, relative to the Rappahannock condition.

Photographic reconnaissance of the bottom north of Rappahannock Shoals in 40-45 feet of water during a hypoxic event documented stress behaviors of many polychaetes and *Cerianthеopsis*, the burrowing sea anemone. Some worms were lying on the sediment surface. Others had their tails extended up into the water column. Both these behaviors are not normal for worms that are subsurface dwellers. Whether or not hypoxia kill these affected individuals or inhibit their recovery is unknown. Also unknown is how hypoxia affects the energy transfer from the benthos to fisheries species.

Program VI. Estuarine Plant Communities

The distribution and abundance of submerged aquatic vegetation (SAV) was mapped for the entire Chesapeake Bay and its tributaries and Chincoteague Bay in 1986 using color aerial photography at a scale of 1:24,000. Groundtruth information was available from the U.S. Geological Survey, Maryland Department of Natural Resources, University of Maryland, Horn Point Laboratory, Harford Community College and VIMS. Citizen support via the Chesapeake Bay Foundation and Citizens Program for the Chesapeake Bay, as well as Maryland's Charterboat Association via Maryland's DNR Watermen's Assistance Program, provided additional groundtruth support.

In 1986, the Chesapeake Bay had 19,759 hectares of SAV, an increase of 2% over the 19,390 hectares in 1985. The Upper Bay zone had 3,420 hectares of SAV in 1986 (17.3% of the total SAV in the Bay). This represents a decrease of 13.1% from that reported in 1985. Sixty-eight percent of the SAV in this zone was located in the Susquehanna Flats section. Overall, the density of the remaining SAV appears to be increasing in this area. Two sections showed decreases in SAV abundance (Upper Eastern Shore - 44%; Chester River - 49%), while two sections showed increased abundance (Susquehanna Flats - 16%; Upper Western Shore - 185%). SAV beds in the Upper Bay zone consisted of 13 species. Dominant species in the Susquehanna Flats were *Myriophyllum spicatum*, *Hydrilla verticillata*, and *Vallisneria americana*, while the Chester River was dominated by *Potamozeton perfoliatus* and *Ruppia maritima*.

The Middle Bay zone had 4,003 hectares of SAV in 1985 (20.3% of the total SAV in the Bay), which represents a 20% decrease from that reported in 1985 but still substantially more than what was reported in 1984 (984 hectares). Two sections in the zone showed an increase in SAV (Middle Eastern Shore - 11.5% and the Upper Potomac River - 11.9%) while six sections showed decreases (Central Western Shore - 96.1%; Eastern Bay - 31.5%; Choptank River - 70.4%; Patuxent River - 56.8%; Middle Western Shore - 73.9%; Lower Potomac River - 5.8%).

SAV beds in the mainstem of the Middle Bay zone consisted principally of *Ruppia maritima*, with about six other species being reported. The Potomac River SAV beds consisted of fourteen different species, with the most prevalent being *Myriophyllum spicatum* and *Hydrilla verticillata.*

SAV in the Upper Potomac River continues its rapid spread. SAV has spread about 9 km further downstream from what was observed in the tidal freshwater portion in 1985. Although *H. verticillata* is one dominant species, other species coexist and, in some areas, share the dominant role with *H. verticillata.*

The Lower Bay zone had 12,336 hectares of SAV in 1985 (62.4% of the total SAV in the Bay), an increase of 8.4% since 1985. Seventy-one percent of the SAV in this zone is found along the bayside of the Eastern Shore, with the major beds being located on the broad, shallow flats in and adjacent to Tangier and Smith islands. The Tangier Island Complex represents the largest concentration of SAV in the entire Bay (32.5% of all the SAV noted in 1986 was located in this section). SAV beds are also concentrated at the mouths of the major bayside creeks, principally Cherrystone Inlet, Hungars Creek, Mattawoman Creek, Occahannock Creek, Craddock Creek, Pungoteague Creek and Onancock Creek. SAV has continued to increase in this section since the first baywide survey was conducted in 1978. Along the western shore of the zone, SAV beds are found in the Back River, Drum Island Flats adjacent to Plum Tree Island, the mouth of the York River adjacent to the Guinea Marshes, along the shoreline of the Mobjack Bay, and in a small band from New Point Comfort to Horn Harbor.

SAV beds here consist of principally two species, *Zostera marina* and *Ruppia maritima*. *Zannichelia palustris* has also been found in small isolated patches, but is not considered a dominant species.

SAV was still absent in two of the six historical areas from the lower Bay zone (Mumfort Island and Parrott Island). SAV decreased in the Jenkins Neck area (13%), but compared with 1985, there were increases in the East River (35%), Fleets Bay (14%) and Vaucluse Shores (11%).

Zostera marina plants transplanted to unvegetated areas in the Piankatank and York rivers between 1982 and 1985 have persisted, and in some cases, are rapidly expanding. These areas are being closely monitored by VIMS' scientists to assess overall changes in distribution of these transplants with time.

SAV in the Chincoteague Bay was mapped for the first time in 1986, with 2,135 hectares found in four areas along the eastern side of the Bay behind Assateague Island: west of the northern end of Chincoteague Island; West Bay; Green Run Bay; and the Tingles Island area. SAV beds constitute approximately 6.6% of the total Bay bottom area from Ocean City, Maryland, to the southern end of Chincoteague Bay. *Z. marina* and *R. maritima* were the two species found growing in these areas.

Tidal Marsh Inventory Program. The Virginia Institute of Marine Science is mandated in the Wetlands Act of 1972 to evaluate, classify and inventory tidal wetlands in the Commonwealth.

An evaluation and classification system was established in the early 1970's and published in a report titled **Coastal Wetlands of Virginia: Wetland Guidelines** Interim Report #3 in 1974. The publication was later promulgated by VMRC as **Wetland Guidelines.**

The wetland inventory program began in 1972 and continued until 1981, when budget shortfalls made it impossible to support the program. In this time period, 23 reports were published and distributed, totalling 13,000 copies.

The marsh inventory reports are an integral part of the wetland resource management program in the Commonwealth. They are utilized by local wetland boards, state and federal agencies, developers, utility companies, marine contractors, consulting firms, planning commissions and en-

vironmental organizations. The most recent inventory report to be published was for the City of Norfolk in March 1987.

Because of an anticipated funding increase beginning on 1 July 1987, which includes a laboratory specialist and an expanded operating budget, plans are being made to publish nine unfinished inventories in the next several years. It is anticipated that three inventories will be completed during 1987-1988. In the near future, those inventories that are ten years old or older will be revised and reproduced in a new format, utilizing current remote sensing data and techniques.

Program VII. Coastal Erosion

The objectives of this program are to measure and monitor tidal shoreline changes in terms of erosion rates, land use and anthropogenic effects in the Commonwealth.

Rates of tidal shoreline erosion in Virginia which took place approximately between the years 1880 and 1950, were measured by comparing shoreline positions from maps in the Shoreline Inventory. Shoreline changes and erosion rates for selected reaches are calculated by comparing aerial photography in the Shoreline Inventory from 1937 to the present.

In 1985 the Shoreline Inventory Computer Database was created at VIMS. It is an update of the Shoreline Situation Reports for Virginia, and compares aerial slides taken in 1975 and aerial videos taken in 1985 of tidal estuarine shoreline. Parameters measured and compared include shoreline erosion rates, beach type, land use, and types of shoreline structures. Tidal shoreline aerial videos are planned for every five years. In addition, ongoing aerial records are kept for site specific areas of interest to the Commonwealth such as the public beaches, Sandbridge, and Cedar Island.

Ground surveys of all public beaches in Virginia are provided by those localities to the Shoreline Section as part of the Shoreline Inventory. These surveys measure beach erosion rates and provide baseline data for beach nourishment projects. Selected type sites are surveyed annually and provide "long-term" erosion rates as well as the type and amount of sediments being eroded in the Chesapeake Bay Estuarine System.

A Sediment Inventory, consisting of beach and nearshore samples collected at regular spatial and temporal intervals, is being organized. Changes in sediment source and probable effects of sediment size on shoreline recession rates are documented.

Program VIII. Physical and Chemical

Dissolved Oxygen and Nutrient Enrichment. The Institute has continued to participate in the cooperative monitoring efforts on Chesapeake Bay. These semi-monthly surveys have provided a new look at the Bay. Preliminary results indicate that water quality varies significantly over rather short time intervals and that problems of low-dissolved oxygen affect a large portion of the Virginia waters. Year-to-year variations also are large. These results illustrate the danger of comparing data from different time periods to show water quality trends. Those differences which exist could be due to climatic or other short-term variations, such as mixing related to spring tides, or they could be due to man's activities. While the changes would be clearly seen, the reasons for those changes would not be clear. Thus citizens, managers, and scientists all should be cautious when attempting to determine water quality trends in the Bay.

Environmental Monitoring at Gloucester Point. The Institute has been monitoring environmental conditions at its Gloucester Point campus for about thirty years. During the past year, funding from private sources has upgraded this effort dramatically. Heretofore, the data have been recorded on strip charts. Subsequently, it was necessary to transfer the data into a digital format and then enter those numbers into computer files. Presently small microprocessors are used to log the signals from the sensing devices and store the data directly in a digital format. For some measurements, strip charts have been retained to provide a quick visual means of examining trends.

Two data loggers have been installed: one on the roof of Byrd Hall logs data on wind speed and direction, rainfall, and solar radiation; the other logger has been installed on the Ferry Pier and records water temperature and salinity, air

temperature, and relative humidity. Both instruments are capable of handling additional sensors, should the need for the data arise. During the coming year the feasibility and desirability of measuring tide levels by using pressure transducers that mesh with this system will be assessed.

Telephone lines have been installed connecting these two data loggers with the central computer at the Institute. Computer programs have been written which have the computer automatically retrieve data from both data loggers each day. Additional software is being prepared to allow students and scientists to access the data files, plot portions of the data, and determine what the present conditions are. The end result is that more data are readily available for use in research projects and the quality of the data is greatly enhanced.

Effluent Monitoring. A program examining industrial and municipal effluents, sediments of receiving waters and associated biota has been undertaken. The purpose of the program is to identify effluents contributing toxics to the Chesapeake Bay and contiguous waters, and to establish an inventory of pollutants present in the system. Sediments are extremely useful for monitoring since they function as repositories for compounds of low water solubility. Shellfish are also being examined as part of the program. These biota accumulate lipophilic compounds and serve as chroniclers of past and present pollution events, as well as indicators of impacts on the *in situ* aquatic biota.

An analytical methodology has been developed which allows the detection of a myriad of toxic organic compounds. The technique employs high performance liquid chromatography (HPLC) and high resolution gas chromatography (HRGC) to resolve the environmental contaminants. Quantitation is accomplished via carbon and chlorine selective detectors. Compound identification is provided by mass spectrometry.

Data obtained from this program is being submitted to the Virginia State Water Control Board (SWCB). The SWCB is using this information in reviewing discharge permits and in recommendations to dischargers in its efforts to reduce the introduction of toxics into Virginia waters. In addition, the program allows early detection of potential future environmental problems prior to the onset of obvious acute/chronic toxic effects. The information obtained is also being entered into the SWCB Data Base for future use. Thirty sites are scheduled for examination in 1986-1987.

Virginia Water Control Board Data Base. A computer database of organic compounds and metals in Virginia's aquatic environment has been established. Concentrations of chemicals in some 150 sediment, biological tissue, industrial effluent, and water column samples are already accessible at the VIMS Computer Center. Data retrieval programs allow keyed searches of the database through terminals at VIMS or by telephone link. Existing Water Control Board historical data as well as new data generated at VIMS and other contributing laboratories are regularly incorporated to provide a background baseline as well as current information on the chemical compounds in Virginia's waters. Database searches have produced useful correlations in the spread of certain compounds from point source effluents to adjacent sediments and organisms.

Tributyltin Monitoring. Tributyltin (TBT) is a biocide used in many formulations of antifouling paints. It is toxic to some aquatic species at concentrations less than 100 parts per trillion. VIMS initiated a TBT water monitoring program in January 1986 and is continuing to collect and analyze samples from marina areas. This TBT water data set is probably the most extensive one in the world. In addition, analytical methodologies for TBT determinations in sediment and tissues have been developed. VIMS is using these to analyze for the biocide in sediments and oysters. Concentrations of over 1 part per million have been collected in both mediums in areas of high boating activities.

Early Warning - Chlorinated Hydrocarbons. Finfish samples for chlorinated hydrocarbons analysis were purchased from wholesale distributors collecting seafood from Virginia waters. Eighty-two fish samples collected from the upper and lower tidal region of the James River have been analyzed. The species analyzed include bluefish, trout, spot, eel and striped bass.

The mean total PCB (polychlorinated biphenyl) concentration in bluefish from the lower

James River during September 1986, was 1.6 ppm (ppm = parts per million). The mean total PCB concentration for trout from the same area of the James River during October 1986, was 1.6 ppm. Total chlordane concentrations were less than 100.0 ppb (ppb = parts per billion).

The samples of striped bass and eel from the upper James River contain an unknown chlorinated compound. A small number of samples from the lower James River may also contain the unknown. It is not possible to estimate the concentrations or significance of the unknown. Efforts are being concentrated on the isolation and identification of this unknown compound.

Kepone. Kepone continues to present problems to the Commonwealth's commercial fishing industry by concentrating in some species of finfish to levels which exceed the established action level (0.3 ppm). The taking of striped bass and eels (unless depurated for 50 days) is prohibited year-round, while the taking of bluefish, croaker and grey trout is prohibited 1 July - 31 December. This year VIMS analyzed over 700 samples to determine concentrations of Kepone.

Research on Kepone indicates that it can produce chronic and acute effects on marine and freshwater animals. However, the levels necessary to produce such effects appear to be considerably greater than those found in the James River.

Continued monitoring of Kepone levels in the James River is necessary to protect public health and provide a long-term record, as an example of a persistent nondegradable pesticide in an estuarine system.

Advisory Activities

Marine Advisory Services, working with clam harvesters, initiated a research project to improve clam relaying. Using cages like the one pictured, the project demonstrated that losses associated with moving the clams to approved growing waters can be significantly reduced; saving industry time and money.

MARINE ADVISORY SERVICES ACTIVITIES

Marine Advisory Services (MAS) provides one of the most visible and responsive services within the Commonwealth to private citizens, marine-related industries, and state-wide educational programs. Often, Advisory Services personnel and publications are the only contact citizens and businesses have with members of the marine science community. Advisory Services personnel specialize in marine-related areas; and the Department offers comprehensive programs in commercial fisheries, education, communication and marine-related trades and recreation.

Commercial Fisheries. Export market expansion efforts for Virginia fisheries products continues to be a successful element of Advisory efforts. Programs initiated several years ago have now become well-established, involving the Virginia Agricultural/Consumer Services and the Gulf and South Atlantic Fisheries Development Foundation.

After initiating the concept of overseas markets for soft shell blue crabs, MAS representatives turned their attention to ocean scallops

(the highest valued seafood product harvested by the Virginia industry), hard clams, and crabs. As with the soft shelled crab initiative, MAS researched market potential and directed efforts toward the Hong Kong and Japanese markets. Several potential Hong Kong and Japanese importers are now evaluating Virginia scallops, crabs and clams for import.

Analysis of sea scallop shell stock continues with samples provided by vessels landing in Seaford and Newport News. This work involves the analysis of shell height and meat weight relationship as they pertain to season, spawning cycle and geographic location. These relationships are important to resource managers and have significant economic ramifications for industry. This work is in cooperation with the East Coast Fisherman's Association and the National Marine Fisheries Service (NMFS).

As a direct result of research, advisory services and industry efforts initiated in 1985, State approval was granted in early 1987 for the relaying of polluted clams by cages for the industry. The use of metal cages for clam relaying reduces losses for industry from 20%-30% to a more acceptable 5%. One firm currently uses 300 cages and has plans to double this number for the 1988 relaying season.

The oyster hatchery outreach program has proven to be a successful and popular program. In 1987 over 100 million eyed larvae were transported to various coastal locations for use in remote setting tanks. Studies of 1986 nursery site successes and failures led to improved setting methods and site selection in 1987. 1986-1987 saw the initiation of two scale-up setting operations using VIMS produced larvae. A 1500 bushel project was begun on Chuckatuck Creek and a 900 bushel project was begun in the East River, Mobjack Bay in collaboration with private oyster growers.

Advisory Services continues to provide essential technical assistance to the soft crab shedding industry, with emphasis on the maintenance of water quality parameters in closed, recirculating systems. The production of soft crabs continues to expand as the demand for this gourmet item increases. Technical advances in system design and maintenance provided to industry has led to a decreasing number of shedding related mortalities and an increase in shedding capacity per system.

Marine Recreation and Marine Trades. In 1986 Advisory personnel published a report of their survey of Norfolk's Harborfest Celebration. This annual event attracts three hundred thousand to four hundred thousand visitors a year and generates revenues in excess of $9 million. As a direct result of the study, water-related activities are receiving more emphasis during the festival. The study helped reinforce the role played by the festival in drawing residents and tourists to the developing waterfront.

Recreational fishing continues to be one of the fastest growing sports in the U.S. Virginia saltwater fishermen spent an estimated $93.5 million in 1986. Increased awareness of the importance of the recreational fishery in overall fisheries management has led to increased studies by advisory personnel to characterize and assess the impacts of the recreational fishery. The VIMS' Recreational Specialist has been appointed to the Recreational Fisheries subcommittee of the Atlantic States Marine Fisheries Commission. The subcommittee's immediate agenda is to address controversial saltwater licensing proposals and improve data collection.

A recreational fishery data collecting effort has been initiated to determine fishermen's use rates and fishing productivity on state maintained artificial reefs in Chesapeake Bay and offshore waters. A special chart was printed showing all artificial reef locations and their Loran C coordinates. The artificial reef fishing study, funded through Wallop-Breaux funds and VIMS, should assist the Virginia Marine Resources Commission in future expansion of its reef program.

A continuing data collection project is a cooperative project between VIMS and NMFS. Through this agreement, the Recreational Specialist coordinates data gathering of part-time fishery reporting aides on Virginia's recreational pelagic fishery for tuna and billfish. The resulting data is used by both VIMS and NMFS in estimating annual catches of targeted pelagic species, particularly bluefin and yellowfin tuna, as well as white and blue marlin.

Through Wallop-Breaux funding in 1987, this project has been expanded to include research efforts on tuna handling practices aboard Virginia

boats and effects of various handling practices on fish quality. A baseline of catch trend data and socioeconomic aspects of Virginia's marlin and tuna fisheries is being established through this overall project.

In early 1987 the Recreational Specialist participated in developing a proposal in response to a request of the Virginia Health Department for a boater education program on voluntary no-discharge of marine sanitation devices. To be funded as part of the Chesapeake Bay Initiatives, the project will develop public information and educational concepts to encourage boaters to use pump-out facilities and to have sewage retention capabilities onboard to complement existing marine sanitation devices. The Recreational Specialist also serves on the Virginia Boating Advisory Board which interacted with the Health Department in developing the voluntary no-discharge concept.

Increased interaction with the recreational fishing public has included continuing the series of Sportfishermen's Forums, presentations to a number of fishing clubs, and a workshop for fishing tournament organizers. Fishing tournaments are increasing state-wide and generate substantial income for cities and localities sponsoring the events.

In cooperation with the School of Business Administration at the College of William and Mary, Advisory personnel organized and presented two extremely well-attended and successful Venture Capital Forums during 1986-1987. The Hampton Roads Venture Capital Forums bring together entrepreneurs and individuals or businesses with investment capital. In addition to the School of Business, sponsors included the Center for Innovative Technology and the Arthur Young Company.

Marine Education. Now completing its second year, the Virginia Bay Team which provides in-class lessons about the Chesapeake Bay has achieved recognition as one of the top marine science education programs in the nation. This past year a second teacher was added and the program involved over 18,000 students and 500 teachers, many of whom had never seen the Chesapeake Bay. They received instruction about the Bay ecosystem and its importance to Virginia. The project is funded through the Council on the Environment as part of Virginia's Chesapeake Bay clean-up program.

Through a new cooperative program with VIMS and Christchurch School an unusual program combining education and research has been created. Basic research data collected through the program is submitted to VIMS for use by VIMS' scientists. Advisory personnel helped design this innovative program for high school students.

Education specialists within the Department continue to assist the Virginia Resource Use Education Council in presenting four graduate level education courses for teachers each summer. The Education Coordinator chairs the Course Committee for the Council and arranges for marine science instructors.

For the third year, VIMS' Advisory Services hosted the Virginia NASA/VIMS Governor's School, a six-week summer program for forty-four gifted and talented Virginia high school students sponsored by the Virginia Department of Education. The program matches students with scientists who volunteer their time to act as mentors for the students. This year, closing ceremonies were held at VIMS for both NASA and VIMS Governor's School participants.

The Seafood Education Seminars coordinated by VIMS and Virginia Polytechnic Institute and State University advisory personnel completed its third series of "standing-room-only" programs. This program combines the expertise of chefs from Tidewater restaurants with wine specialists from Virginia wineries to educate the general public on the benefits and ease of preparing Virginia seafood at home.

A project has been initiated to educate the public on the nutritional value of finfish and shellfish of the Chesapeake Bay and mid-Atlantic states. A VIMS scientist will determine the levels of omega-3 and omega-6 polyunsaturated fatty acids of local seafood and a series of publications, news releases and media appearances will be used to inform the public.

Advisory Education personnel also coordinated the National Youth World of Water Awards Program, sponsored by the National Marine Educators Association. The program provides students who have won science fairs at the local, state or regional levels the opportunity to

achieve national recognition for their water-related projects.

Advisory Services continued to coordinate media relations for the Institute. There were regular television appearances by VIMS' scientists and advisory personnel in areas of research, conservation and resource education.

The VIMS' Aquarium program continues to expand both in development of new live and static displays, and through increasing membership in the docent (volunteer) program. This past year a 200 gallon "touch-tank" containing harmless marine invertebrates such as sea stars, hermit crabs and horseshoe crabs was established, intriguing and delighting visitors. Additionally, a small bookstore/gift shop has been installed in the aquarium lobby. Profits will fund aquarium public education programs.

Animals for the VIMS aquarium are collected by aquarium staff, or cooperatively with other Institute scientists. The aquarium also helps other museums and aquariums throughout the State obtain live marine animals for their displays.

A "mobile" version of the touch tank was taken to the 1987 Norfolk Harborfest on board the VIMS' research vessel R/V CAPTAIN JOHN SMITH and was one of the most popular exhibits at the festival.

Publications and Communications. Periodicals produced by Advisory Services include: the **Marine Resource Bulletin** (quarterly, circulation 6,800); **Commercial Fishing Newsletter** (Quarterly, circulation 6,900); **Tide Graphs for Hampton Roads and Wachapreague** (quarterly, circulation 500). These publications reach managers, politicians, educators, scientists and the general public. In a recent survey of the **Marine Resource Bulletin** readership, a large number of respondents praised the information and educational value of the only publication in Virginia specifically devoted to the marine environment.

During the past year, Advisory Services responded to 4,771 requests for MAS publications. These publications range from technical reports for specific fisheries and marine-related industries, to general interest and educational publications and advisories for industry, describing specific conditions or circumstances which will affect the commercial fishing industry.

ADVISORY ACTIVITIES OF RESEARCH STAFF

Fisheries. VIMS fisheries scientists serve as advisors to the Virginia Marine Resources Commission (VMRC), as members of the VMRC Fisheries Management Advisory Committee, and the Potomac River Fisheries Commission (PRFC). Five individuals continue membership on the Scientific and Statistics Committee for striped bass, weakfish, menhaden, shad and river herring, flounder, and bluefish for the Interstate Fisheries Management Program of the Atlantic States Marine Fisheries Commission (ASMFC). One continues to serve as the Virginia representative on the ASMFC Advisory Committee. Others serve on the Scientific and Statistics Committee of the Mid-Atlantic Fisheries Management Council, the James River Fish Passage Committee, and the ASMFC striped bass stock enhancement committee.

During 1986-1987 fisheries scientists continued to work with the Chesapeake Bay Commission on issues concerning fisheries management. One continued membership on the EPA Bay Program Monitoring Sub-committee, and two continued to serve on the NOAA Chesapeake Bay Stock Assessment Committee (CBSAC). Six scientists were members of the various working groups of CBSAC for data bases coordination, data interpretation, and development of a Status of Stocks report.

Wetlands Advisory. In response to the Institute's educational and advisory mandates, personnel of the Wetlands Advisory Group are an integral part of the Commonwealth's Coastal Resources Management Program (CRMP). Their efforts include: scientific and technical review of shoreline permit applications; the coordination of the Institute's responses to environmental impact statements (both the State program and the National Environmental Policy Act (NEPA); and the review of National Pollutant Discharge Elimination System (NPDES) permit applications. Personnel are also active in the development of legislation and management guidelines pertaining to wetlands and dunes, as well as conducting training sessions

and educational seminars and workshops for environmental managers. This educational effort affords those charged with regulatory responsibilities with the opportunity to acquire the basic scientific knowledge necessary to carry out their management objectives.

More specifically, Wetlands Advisory Group personnel serve as scientific and technical advisors for review of permit applications for wetlands, coastal primary sand dunes and subaqueous lands. The scientists reviewed approximately 1,738 shoreline applications and responded to numerous requests from citizens for pre-application advice. Because of the significant annual increases in numbers of applications received since 1983, plans were made to add two additional Marine Scientists to the Wetlands staff beginning in July of 1987.

Personnel of the Wetlands Advisory Program also coordinated Institute comments on seven environmental impact statements and twelve NPDES applications involving effluent releases into tidal waters. One paper was presented at a national symposium and will be published in the journal, **Wetlands.** A major effort went into the development of wetland mitigation/compensation guidelines for use by the Virginia Marine Resources Commission and the local wetlands boards. As part of the advisory mandate, Wetlands personnel attended the regular meetings of the following groups which generally meet monthly: State/federal Joint Permit Processing Group; Local Wetlands Boards (31); U. S. Army Corps of Engineers (federal dredging project reviews); Virginia Department of Transportation Environmental Coordination meeting; and the Virginia Marine Resources Commission.

Personnel of the Wetlands Group developed a proposal which was submitted to Virginia's Coastal Resources Management Program requesting funds for the purchase and operation of a data retrieval software package. This system, in combination with the VIMS mainframe, will allow for the first time the tracking of the numerous applications under review and will enable VIMS to greatly expand the data base upon which it relies in advising the permitting agencies, particularly where cumulative effects are an issue within the permit program.

Nutrient-related Water Quality Standards. The Virginia State Water Control Board has initiated procedures to establish water quality standards that will address problems of nutrient enrichment. Scientists from the Institute have been involved in a number of ways including testifying at public hearings, staff discussions, discussions with legislators, and technical advisory committee meetings.

Chesapeake Bay Program. The Associate Director for Research serves on the Modelling and Research Subcommittee, and the Assistant Director for Physical Oceanography serves on the Monitoring Subcommittee. Other scientists serve on various ad hoc committees.

Shellfish. Filter feeding organisms tend to accumulate pollutants to levels far in excess of those found in the water. Consequently, pollution often adversely affects the shellfish industry long before other resource users of the water are impacted. Scientists from the Institute have been involved with the Interagency Task Force on Shellfish Resources since its inception. Present efforts are aimed towards automation of data bases and eventually the sharing of data among concerned agencies. The long-range goal is improved management of the resource. The Shellfish Enhancement Task Force has a similar goal, but the emphasis is on coordination of efforts now to maximize the benefits. VIMS scientists advise the task force on issues relating to water pollution, microbiology, and nonpoint source pollution.

THIS PAGE LEFT INTENTIONALLY BLANK

Appendices

THIS PAGE LEFT INTENTIONALLY BLANK

APPENDIX I

THE FACULTY OF THE SCHOOL OF MARINE SCIENCE

Gary F. Anderson, Instructor in Marine Science. B.S., Southampton College of Long Island University; M.A., the College of William and Mary. Physical Oceanography and Environmental Engineering.

Jay D. Andrews, Professor Emeritus of Marine Science. B.S., Kansas State College; M.A., Ph.D., University of Wisconsin. Marine Fisheries Science.

Herbert M. Austin, Professor of Marine Science. B.S., Grove City College; M.S., University of Puerto Rico; Ph.D., Florida State University. Marine Fisheries Science.

Thomas A. Barnard, Jr., Assistant Professor of Marine Science. B.A., Milligan College; M.A., the College of William and Mary. Marine Resource Management.

Susan O. Barrick, Librarian. B.S., Shepherd College; M.L.S. Case Western Reserve. Marine Resource Management.

Michael E. Bender, Professor of Marine Science. B.A., Southern Illinois University; M.S., Michigan State University; Ph.D., Rutgers University. Biological Oceanography.

Rudolf H. Bieri, Professor of Marine Science. Dr.rer.nat. Johann Gutenberg University. Chemical Oceanography.

Robert E. Lee Black, Professor of Biology and Marine Science. A.B., William Jewell College; M.A., Ph.D., University of Washington. Biological Oceanography.

John D. Boon, III, Professor of Marine Science. B.A., Rice University; M.A., Ph.D., the College of William and Mary. Geological Oceanography.

John M. Brubaker, Assistant Professor of Marine Science. A.B., Miami University; Ph.D., Oregon State University. Physical Oceanography and Environmental Engineering.

Eugene M. Burreson, Associate Professor of Marine Science. B.S., Eastern Oregon College; M.S., Ph.D., Oregon State University. Biological Oceanography.

Robert J. Byrne, Associate Director for Research and Professor of Marine Science. M.S., Ph.D., University of Chicago. Geological Oceanography.

Michael Castagna, Professor of Marine Science. B.S., M.S., Florida State University. Biological Oceanography.

Carl. F. Cerco, Assistant Professor of Marine Science. B.S., Newark College; M.S., University of North Carolina and Massachusetts Institute of Technology; Ph.D., the College of William and Mary. Physical Oceanography and Environmental Engineering.

Mark E. Chittenden, Jr., Professor of Marine Science. B.A., Hobart College; M.S., Ph.D., Rutgers University. Marine Fisheries Science.

Fu-Lin Chu, Assistant Professor of Marine Science. B.S., Chung Chi College; M.S., University of Rochester; Ph.D., the College of William and Mary. Biological Oceanography.

Ashok D. Deshpande, Assistant Professor of Marine Science. B.A., M.S., University of Poona; Ph.D., National Chemical Laboratory. Chemical Oceanography.

Robert J. Diaz, Associate Professor of Marine Science. B.A., LaSalle College; M.S., Ph.D., University of Virginia. Biological Oceanography.

William D. DuPaul, Professor of Marine Science. B.S., Bridgewater State College; M.A., Ph.D., the College of William and Mary. Marine Fisheries Science.

Lehman L. Ellis, Assistant Professor of Marine Science. B.S., University of Texas at Arlington; Ph.D., University of South Carolina. Biological Oceanography.

David A. Evans, Associate Professor of Marine Science. B.A., M.A., Cambridge University; Ph.D., Oxford University. Physical Oceanography and Environmental Engineering.

Mary C. Gibbons, Assistant Professor of Marine Science. B.A., M.S., University of Delaware; Ph.D., State University of New York at Stony Brook. Biological Oceanography.

George C. Grant, Professor of Marine Science. B.S., University of Massachusetts; M.A., the College of William and Mary; Ph.D., University of Rhode Island. Biological Oceanography.

John Greaves, Assistant Professor of Marine Science. B.Sc., Leeds University; Ph.D., Liverpool University. Chemical Oceanography.

Leonard W. Haas, Associate Professor of Marine Science. A.B., Dartmouth College; M.S., University of Rhode Island; Ph.D., the College of William and Mary. Biological Oceanography.

Robert C. Hale, Assistant Professor of Marine Science. B.S., B.A., Wayne State University; Ph.D., the College of William and Mary. Chemical Oceanography.

John M. Hamrick, Associate Professor of Marine Science. B.C.E., Georgia Institute of Technology; M.S., Massachusetts Institute of Technology; Ph.D., University of California, Berkeley. Physical Oceanography.

William J. Hargis, Jr., Professor of Marine Science. A.B., M.A., University of Richmond; Ph.D., Florida State University. Biological Oceanography.

Dexter S. Haven, Professor Emeritus of Marine Science. B.S., M.S., Rhode Island State College. Marine Fisheries Science.

Carl H. Hershner, Associate Professor of Marine Science. B.S., Bucknell University; Ph.D., University of Virginia. Marine Resource Management.

Bruce W. Hill, Lecturer in Marine Science. B.S., Christopher Newport College; M.S., Old Dominion University. Marine Fisheries Science.

Carl H. Hobbs, III, Assistant Professor of Marine Science. B.S., Union College; M.S., University of Massachusetts. Geological Oceanography.

Robert J. Huggett, Professor of Marine Science. M.S., Scripps Institution of Oceanography; Ph.D., the College of William and Mary. Chemical Oceanography.

Howard I. Kator, Associate Professor of Marine Science. B.S., Harpur College; Ph.D., Florida State University. Biological Oceanography.

Kevin P. Kiley, Instructor in Marine Science. B.S., Tufts University; M.A., the College of William and Mary. Physical Oceanography and Environmental Engineering.

James E. Kirkley, Assistant Professor of Marine Science. B.S., M.S., Ph.D., University of Maryland. Marine Resource Management.

Albert Y. Kuo, Professor of Marine Science. B.S., National Taiwan University; M.S., University of Iowa; Ph.D., The Johns Hopkins University. Physical Oceanography and Environmental Engineering.

Romuald N. Lipcius, Assistant Professor of Marine Science. B.S., University of Rhode Island; Ph.D., Florida State University. Marine Fisheries Science.

Joseph G. Loesch, Professor of Marine Science. B.S., University of Rhode Island; M.S., Ph.D., University of Connecticut. Marine Fisheries Science.

Mark W. Luckenbach, Assistant Professor of Marine Science. B.S., University of North

Carolina; Ph.D., University of South Carolina. Biological Oceanography.

Jon A. Lucy, Instructor in Marine Science. B.S., University of Richmond; M.A., the College of William and Mary. Marine Fisheries Science.

Robert J. Lukens, Instructor in Marine Science. B.S., Massachusetts Institute of Technology. Physical Oceanography and Environmental Engineering.

Maurice P. Lynch, Associate Dean and Professor of Marine Science. A.B., Harvard University; M.A., Ph.D., the College of William and Mary. Marine Resource Management.

Jerome P.-Y. Maa, Assistant Professor of Marine Science. B.S., University of Taiwan; M.S., Cheng-Kong University; Ph.D., University of Florida. Geological Oceanography.

William G. MacIntyre, Professor of Marine Science. B.S., M.S., Ph.D., Dalhousie University. Chemical Oceanography.

Roger L. Mann, Professor of Marine Science. B.S., University of East Anglia; Ph.D., University of Wales. Marine Fisheries Science.

Brian W. Meehan, Assistant Professor of Marine Science. B.S., Wagner College; M.S., University of Bridgeport; Ph.D., the College of William and Mary. Marine Fisheries Science.

Kenneth A. Moore, Instructor in Marine Science. B.S., Pennsylvania State University; M.S., University of Virginia. Biological Oceanography.

John A. Musick, Professor of Marine Science. A.B., Rutgers University; M.A., Ph.D., Harvard University. Marine Fisheries Science.

Bruce J. Neilson, Professor of Marine Science. B.A., M.S.E., M.A., Princeton University; Ph.D., The Johns Hopkins University. Physical Oceanography and Environmental Engineering.

Maynard M. Nichols, Professor of Marine Science. B.S., Columbia University; M.S., Scripps Institution of Oceanography; Ph.D., University of California at Los Angeles. Geological Oceanography.

Brenda L. Norcross, Assistant Professor of Marine Science. A.B., MacMurray College; M.S., St. Louis University; Ph.D., the College of William and Mary. Marine Fisheries Science.

John E. Olney, Assistant Professor of Marine Science. B.S., M.A., the College of William and Mary. Biological Oceanography.

Robert J. Orth, Associate Professor of Marine Science. B.S., Rutgers University; M.A., University of Virginia; Ph.D., University of Maryland. Biological Oceanography.

Frank O. Perkins, Dean and Professor of Marine Science. B.A., University of Virginia; M.S., Ph.D., Florida State University. Biological Oceanography.

Walter I. Priest, III, Instructor in Marine Science. B.S., Virginia Military Institute; M.S., Old Dominion University. Marine Resource Management.

Martha W. Rhodes, Instructor in Marine Science. B.S., Virginia Polytechnic Institute and State University; M.A., Medical College of Virginia, Virginia Commonwealth University. Biological Oceanography.

Morris H. Roberts, Jr., Professor of Marine Science. B.A., Kenyon College; M.A., Ph.D., the College of William and Mary. Biological Oceanography.

Evon P. Ruzecki, Associate Professor of Marine Science. A.B., Knox College; M.S., University of Wisconsin; Ph.D., University of Virginia. Physical Oceanography and Environmental Engineering.

Michael E. Sieracki, Assistant Professor of Marine Science. B.A., University of Delaware; M.S., Ph.D., University of Rhode Island. Biological Oceanography.

Gene M. Silberhorn, Professor of Marine Science. B.S., Eastern Michigan University; M.S., West Virginia University; Ph.D., Kent State University. Biological Oceanography.

Craig L. Smith, Associate Professor of Marine Science. A.B., The Johns Hopkins University; Ph.D., University of Florida. Chemical Oceanography.

N. Bartlett Theberge, Jr., Professor of Marine Science. B.S., J.D., the College of William and Mary; LL.M., University of Miami. Marine Resource Management.

Willard A. Van Engel, Professor Emeritus of Marine Science. Ph.B., Ph.M., University of Wisconsin. Marine Fisheries Science.

Jacques van Montfrans, Instructor in Marine Science. B.S., Florida State University; M.S., Florida Atlantic University. Biological Oceanography.

J. Ernest Warinner, III, Assistant Professor of Marine Science. B.S., M.A., the College of William and Mary. Chemical Oceanography.

Marvin L. Wass, Professor Emeritus of Marine Science. B.S., Winona State College; M.S., Florida State University; Ph.D., University of Florida. Biological Oceanography.

Kenneth L. Webb, Chancellor Professor of Marine Science. A.B., Antioch College; M.S., Ph.D., Ohio State University. Biological Oceanography.

Beverly A. Weeks, Associate Professor of Marine Science. B.A., Winthrop College; M.S. (equiv.) Tulane University, School of Medicine; Ph.D., North Carolina State University. Biological Oceanography.

Richard L. Wetzel, Associate Professor of Marine Science. B.S., M.S., University of West Florida; Ph.D., University of Georgia. Biological Oceanography.

Frank J. Wojcik, Assistant Professor Emeritus of Marine Science. B.S., University of Massachusetts; M.S., University of Alaska. Marine Fisheries Science.

L. Donelson Wright, Professor of Marine Science. B.A., University of Miami; M.A., University of Sydney; Ph.D., Louisiana State University. Geological Oceanography.

ASSOCIATE FACULTY

Gary L. Anderson, B.S., Gustavus Adolphus College; Espey, Houston and Associates.

Carl Richard Berquist, Jr., B.E., M.S., Vanderbilt University; Ph.D., the College of William and Mary. Division of Mineral Resources, Department of Mines, Minerals and Energy.

Donald F. Boesch, B.S., Tulane University; Ph.D., the College of William and Mary. Louisiana Universities Marine Consortium.

Mitchell A. Byrd, B.S., M.S., Ph.D., Virginia Polytechnic Institute and State University. Biology Department, the College of William and Mary.

H. Jacques Carter, B.S., M.S., Northern Illinois University; Ph.D., the College of William and Mary. Wildlife Conservation International.

William E. Cooper, B.S., Michigan State University; M.S., Ph.D., University of Michigan. Michigan State University.

Michael L. Fine, B.S., University of Maryland; M.A., the College of William and Mary; Ph.D., University of Rhode Island. Virginia Commonwealth University.

Robert H. George, B.S., University of Maryland; D.V.M., University of Georgia. Gloucester Veterinary Hospital, Ltd.

John J. Govoni, A.B., St. Anselm's College; M.S., Southeastern Massachusetts University; Ph.D., the College of William and Mary. Southeast Fisheries Center, National Marine Fisheries Service.

C. Scott Hardaway, B.A., M.S., East Carolina University. Virginia Institute of Marine Science.

Robert C. Harriss, B.S. Florida State University; M.A., Ph.D., Rice University. NASA Langley Research Center.

Harold J. Humm, B.S., University of Miami; M.S., Ph.D., Duke University.

G. David Johnson, B.S., University of Texas at Austin; Ph.D., University of California at San Diego. Smithsonian Institution.

Gerald H. Johnson, B.S., M.A., Ph.D., Indiana University. Geology Department, the College of William and Mary.

Suzette M. Kimball, B.A., B.S., the College of William and Mary; M.S., Ball State University; Ph.D., University of Virginia. Virginia Institute of Marine Science.

Martin L. Lenhardt, B.S., M.A., Seton Hall University; Ph.D., Florida State University. Virginia Commonwealth University.

Victor A. Liguori, A.B., Haverford College; M.A., Ph.D., Princeton University. Sociology Department, the College of William and Mary.

Charlotte P. Mangum, A.B., Vassar College; M.S., Ph.D., Yale University. Biology Department, the College of William and Mary.

John V. Merriner, B.A., Rutgers University; M.S., Ph.D., North Carolina State University. Southeast Fisheries Center, National Marine Fisheries Service.

Polly A. Penhale, B.A. Earlham College; M.S., Ph.D., North Carolina State University. National Science Foundation.

William G. Raschi, B.A., State University of New York at Geneseo; M.S., Southeastern Massachusetts University; Ph.D., the College of William and Mary. Bucknell University.

Carl N. Shuster, Jr., B.S., M.S., Rutgers University, The State University of New Jersey; Ph.D., New York University.

Kenneth J. Sulak, B.A., Harvard University; M.S., University of Miami. Huntsville Marine Laboratory, Canada.

Lamar Trott, A.A., St. Petersburg Junior College; B.A., M.A., Florida State University; Ph.D., University of California. University of Hawaii-Manoa.

Ruth D. Turner, B.S., Bridgewater State College; M.A., Cornell University; Ph.D., Radcliffe, Harvard University. Harvard University.

James E. Weaver, B.S., M.S., Louisiana State University; Ph.D., University of Virginia. National Fisheries Center, U.S. Fish and Wildlife Service.

Michael P. Weinstein, B.A., Hofstra University; M.S., Rutgers State University; Ph.D. Florida State University. Lawler, Matusky and Skelly Engineers.

Christopher S. Welch, B.S., Stanford University; Ph.D., Massachusetts Institute of Technology. NASA Langley Research Center.

Scott C. Whitney, A.B., University of Nevada; LL.B., J.D., Harvard Law School. George Mason University.

Lawrence L. Wiseman, A.B., Hiram College; M.A., Ph.D., Princeton University. Biology Department, the College of William and Mary.

Paul L. Zubkoff, B.S., University of Buffalo; M.A., George Washington University; Ph.D. Cornell University. Micro Science Consulting.

APPENDIX II

PUBLICATIONS

Journal and Book Contributions

1125. Briggs, Jesse A., Robert J. Lukens and Jon A. Lucy. 1983. Initial performance analysis of the sail-assisted tug/fishing vessel NORFOLK REBEL - fuel savings and economic return. Pp. 84-118 *in* Shortall, John W., III (ed.), International Conference on Sail-Assisted Commercial Fishing Vessels, Proceedings, Vol. II, addendum to Proceedings of a Conference held May 15-18, 1983 at Tarpon Springs, Florida.

1218. Larsen, Peter F. 1986. The benthic macrofauna associated with the oyster reefs of the James River estuary, Virginia, U.S.A. Internationale Revue der gesamten Hydrobiologie 70:797-814.

1223. Lucy, Jon A., A. Breen and D. Rigby. 1985. Urban waterfronts: Positive directions, new problems. Pp. 66-80 *in* Proceedings of the National Outdoor Recreation Trends Symposium II, Vol. II.

1229. Anderson, Gary L. 1985. Who's minding the beach?...The Virginia experience. Pp. 453-472 *in* Magoon, O. T. et al (eds.), Coastal Zone 1985.

1239. Harvey, Susan E. and Andrew W. Zacherle. 1985. National marine pollution issues -- state and regional perspectives. Pp. 137-150 *in* Gambling with the Shore; Proceedings of the Ninth Annual Conference of The Coastal Society.

1247. Mann, Roger L. 1986. Sampling of bivalva larvae. Pp. 107-116 *in* Jamieson, G. S. and N. Bourne (eds.), North Pacific Workshop on Stock Assessment and Management of invertebrates. Canadian Special Publication of Fisheries and Aquatic Sciences 92.

1249. Weeks, Beverly Anne and J. Ernest Warinner. 1986. Observations on the reproductive biology of the cownose ray, *Rhinoptera bonasus*, *in* Chesapeake Bay. Fishery Bulletin 84:871-877.

1252 Lynch, Maurice P. and Evon P. Ruzecki. 1985. Development of a research plan for a Norfolk Canyon Marine Sanctuary. Pp. 407-413 *in* Lynch, M. P. (ed.), Gambling with the Shore; Proceedings of the Ninth Annual Conference of The Coastal Society.

1255. Ruzecki, Evon P. and David A. Evans. 1986. Temporal and spatial sequencing of destratification in a coastal plain estuary. Pp. 368-389 *in* Bowman, J., M. Yentsch and W. T. Peterson (eds.), Tidal Mixing and Plankton Dynamics (Lecture Notes on Coastal and Estuarine Studies; v. 17).

1256. Hayward, Don M., Leonard W. Haas, John D. Boon, III, Kenneth L. Webb and Kevin D. Friedland. 1986. Empirical models of stratification variation in the York River estuary, Virginia, USA. Pp. 346-367 *in* Bowman, J., M. Yentsch and W. T. Peterson (eds.), Tidal Mixing and Plankton Dynamics (Lecture Notes on Coastal and Estuarine Studies; v. 17).

1261. Weeks, Beverly Anne, J. Ernest Warinner, Patrice L. Mason and Dana S. McGinnis. 1986. Influence of toxic chemicals on the chemotactic response of fish macrophages. Journal of Fish Biology 28:653-658.

1269. Koepfler, Eric T. and Howard I. Kator. 1986. Ecotoxicological effects of creosote contamination on benthic microbial populations in an estuarine environment. Toxicity Assessment: An International Quarterly 1:465-485.

1270. Vecchione, Michael. 1987. A multispecies aggregation of cirrate octopods trawled from north of the Bahamas. Bulletin of Marine Science 40:78-84.

1272. Green, Malcolm O. 1986. Side-scan sonar mosaic of a sand ridge field: Southern Mid-Atlantic Bight. Geo-Marine Letters 6:35-40.

1273. Theberge, N. Bartlett. 1985. Subaqueous minerals management - the Virginia experience. Pp. 400-404 *in* IEEE Oceans '85 Conference Proceedings.

1274. Weeks, Beverly Anne and J. Ernest Warinner. 1986. Functional evaluation of macrophages in fish from a polluted estuary. Veterinary Immunology and Immunopathology 12:313-320.

1275. Ruzecki, Evon P., Paul V. Hyer, Kevin P. Kiley and Mary Sue Jablonsky. 1986. Imaging system techniques applied to analysis of hydraulic and finite element model experiment results. Pp. 211-220 *in* IEEE Proceedings of the Fourth Working Symposium on Oceanographic Data Systems, February 1986, San Diego, California.

1276. Hutton, Cindy Hart, Peter F. DeLisle, Morris H. Roberts, Jr. and Daniel A. Hepworth. 1980. *Chrysaora quinquecirrha*: A predator on mysids (*Mysidopsis bahia*) in culture. The Progressive Fish-Culturist 48:154-155.

1278. Burreson, Eugene M. and Linda J. Frizzell. 1986. The seasonal antibody response to juvenile summer flounder (*Paralichthys dentatus*) to the hemoflagellate *Trypanoplasma bullocki*. Veterinary Immunology and Immunopathology 12:395-402.

1284. Orth, Robert J. and Kenneth A. Moore. 1986. Seasonal and year-to-year variations in the growth of *Zostera marina* L. (eelgrass) in the lower Chesapeake Bay. Aquatic Botany 24:335-341.

1289. Bieri, Rudolf H., Chris S. Hein, Robert J. Huggett, Philip M. Shou, Harold D. Slone, Craig L. Smith and Chih-Wu Su. 1986. Polycyclic aromatic hydrocarbons in surface sediments from the Elizabeth River subestuary. International Journal of Environmental Analytical Chemistry 26:97-113.

1290. Crabtree, Roy E. and Kenneth J. Sulak. 1986. A contribution to the life history and distribution of Atlantic species of the deep-sea fish genus *Conocara* (Alepocephalidae). Deep-Sea Research 33:1183-1201.

1291. DeLisle, Peter F. and Morris H. Roberts, Jr. 1986. The effect of acclimation on salinity tolerance of the mysid, *Mysidopsis bahia* Molenock. Comparative Biochemistry and Physiology 85A:383-387.

1295. Kraeuter, John N. and Michael Castagna. 1985. (1986.) The effect of clam size, net size, and poisoned bait treatments on survival of hard clam, *Mercenaria mercenaria*, seed in field plots. Journal of the World Mariculture Society 16:377-385.

1297. van Montfrans, Jacques, Judith F. Capelli, Robert J. Orth and Clifford H. Ryer. 1986. Use of microwire tags for tagging juvenile blue crabs (*Callinectes sapidus* Rathbun). Journal of Crustacean Biology 6:370-376.

1298. Hershner, Carl H. 1986. Marina sitings from the scientific advisor's viewpoint. Pp. 310-317 *in* Kuo, C. Y. and T. M. Younos (eds.), Effects of Upland and Shoreline Land Use on the Chesapeake Bay; Proceedings of the Chesapeake Bay Research Conference.

1303. Thoney, Dennis A. and Eugene M. Burreson. 1986. Ecological aspects of *Multicalyx cristata* (Aspidocotylea) infections in northwest Atlantic elasmobranchs. Proceedings of the Helminthological Society of Washington 53:162-165.

1304. Raschi, William G. 1986. A morphological analysis of the ampullae of Lorenzini in selected skates (Pisces, Rajoidei). Journal of Morphology 189:225-247.

1305. Smith, Joseph W. and John V. Merriner. 1986. Observations on the reproductive biology of the cownose ray, *Rhinoptera bonasus*, in Chesapeake Bay. Fishery Bulletin 84:871-877.

1306. Haven, Dexter S. and James P. Whitcomb. 1986. The public oyster bottoms in Virginia: an overview of their size, location, and productivity. American Malacological Bulletin, Special Edition no. 3:17-23.

1308. Mann, Roger L. 1986. *Arctica islandica* (Linne) larvae: active depth regulators or passive particles. American Malacological Bulletin, Special Edition no. 3:51-57.

1311. Wright, L. Don, John D. Boon, III, Malcolm O. Green and Jeffrey H. List. 1986. Response of the mid shoreface of the southern mid-Atlantic Bight to a "northeaster." Geo-Marine Letters 6:153-160.

1312. Johnson, James R., Joseph G. Loesch and A. B. Blair. 1986. A morphometrical comparison between cultured and wild juvenile American shad. The Progressive Fish-Culturist 8:168-170.

1314. Pierce, J. W. and Maynard M. Nichols. 1986. Change of particle composition from fluvial into an estuarine environment: Rappahannock River, Virginia. Journal of Coastal Research 2:419-425.

1315. Burris, David R. and William G. MacIntyre. 1986. A thermodynamic study of solutions of liquid hydrocarbon mixtures in water. Geochimica et Cosmochimica Acta 50:1545-1549.

1317. Bender, Michael A., Paul O. deFur and Robert J. Huggett. 1986. Polynuclear aromatic hydrocarbon monitoring in estuaries utilizing: oysters, brackish water clams and sediments. Pp. 791-796 *in* IEEE Oceans '86 Conference Proceedings.

1320. Stauffer, T. B. and William G. MacIntyre. 1986. Sorption of low-polarity organic compounds on oxide minerals and aquifer material. Environmental Toxicology and Chemistry 5:949-955.

1321. Wright, L. Don, D. B. Prior, Carl H. Hobbs, III, Robert J. Byrne, John D. Boon, III, Linda C. Schaffner and Malcolm O. Green. 1987. Spatial variability of bottom types in the lower Chesapeake Bay and adjoining estuaries and inner shelf. Estuarine, Coastal and Shelf Science 24:765-784.

1322. Wright, L. Don et al. 1986. Hyperpycnal plumes and plume fronts over the Huanghe (Yellow River) delta front. Geo-Marine Letters 6:97-105.

1323. Wright, L. Don et al. 1986. Short period internal waves over the Huanghe (Yellow River) delta front. Geo-Marine Letters 6:115-120.

1324. Nichols, Maynard M. 1986. Consequences of sediment flux: escape or entrapment? Rapport et Process-verbaux du Conseil international pour l'Exploration de la Mer 186:343-351.

1325. Nichols, Maynard M. and Mary M. Howard-Strobel. 1986. Man's physical effects on the Elizabeth River. Pp. 166-177 *in* Kuo, C. Y. and T. M. Younos (eds.), Effects of Upland and Shoreline Land Use on the Chesapeake Bay; Proceedings of the Chesapeake Bay Research Conference.

1326. Wright, L. Don, A. D. Short, John D. Boon, III, B. Hayden, S. Kimball and Jeffrey H. List. 1987. The morphodynamic effects of incident wave groupiness and tide range on an energetic beach. Marine Geology 74:1-20.

1328. Huggett, Robert J., Michael A. Unger and Donna J. Westbrook. 1986. Organotin concentrations in the southern Chesapeake Bay. Pp. 1262-1265 *in* IEEE Oceans '86 Conference Proceedings.

1329. Fredette, Thomas J. and Robert J. Diaz. 1986. Secondary production of *Gammarus mucronatus* Say (Amphipoda: Gammaridae) in warm temperate estuarine habitats, York River, Virginia. Journal of Crustacean Biology 6:729-741.

1330. Austin, Herbert M., David A. Evans and Brenda L. Norcross. 1986. Time series analyses as a means of examining long-term biological data sets. Pp. 946-952 *in* IEEE Oceans '86 Conference Proceedings.

1332. Fisher, Daniel J., J. R. Clark, Morris H. Roberts, Jr., J. P. Connolly and L. H. Mueller. 1986. Bioaccumulation of kepone by spot *(Leiostomus xanthurus)*: importance of dietary accumulation and ingestion rate. Aquatic Toxicology 9:161-178.

1334. Weeks, Beverly Anne, Anisa S. Keisler, Q. N. Myrvik and J. Ernest Warinner. 1987. Differential uptake of neutral red by macrophages from three species of estuarine fish. Developmental and Comparative Immunology 11:117-124.

1335. Boyer, Joseph N. 1986. End products of anaerobic chitin degradation by salt marsh bacteria as substrates for dissimilatory sulfate reduction and methanogenesis. Applied and Environmental Microbiology 52:1415-1418.

1336. Rosa, Ricardo S., H. P. Castallo and T. B. Thorson. 1987. *Plesiotrygon iwamae*, a new genus and species of neotropical freshwater stingray (Chondrichthyes: Potamotrygonidae). Copeia 1987(2):447-458.

1337. Weeks, Beverly Anne, J. Ernest Warinner and Elaine S. Mathews. 1986. Finfish as indicators of toxic contamination: Immunological aspects. Pp. 9-11 *in* Background Paper on Methodologies for Toxic Effects on Estuarine Finfish. CMS-04-86. University of Delaware, Newark.

1338. Hargis, William J., Jr., and James A. Colvocoresses. 1986. Use of finfish as indicators of toxic contamination: Selected gross pathological features. Pp. 1-8 in Background Paper on Methodologies for Toxic Effects on Estuarine Finfish. CMS-04-86. University of Delaware, Newark.

1340. Thoney, Dennis A., and Thomas A. Munroe. 1987. *Microcotyle hiatulae* Goto, 1900 (Monogenea), a senior synonym of *M. furcata* Linton, 1940, with a redescription and comments on postlarval development. Proceedings of the Helminthological Society of Washington 54:91-95.

1341. Thoney, Dennis A., and Eugene M. Burreson. 1987. Morphology and development of the adult and cotylocidium of *Multicalyx cristata* (Aspidocotylea), a gall bladder parasite of elasmobranchs. Proceedings of the Helminthological Society of Washington 54:96-104.

1344. Wetzel, Richard L. and Hilary A. Neckles. 1986. A model of *Zostera marina* L. photosynthesis and growth: simulated effects of selected physical-chemical variables and biological interactions. Aquatic Botany 26:307-323.

1351. Boon, John D., III, W. F. Bohlen and L. Don Wright. 1987. Estuarine versus inner shelf disposal sites: a comparison of benthic current regimes. Pp. 571-583 *in* Kraus, N. C. (ed.), Coastal Sediments '87.

1352. Schaffner, Linda C. Robert J. Diaz and Robert J. Byrne. 1987. Processes affecting recent estuarine stratigraphy. Pp. 584-599 *in* Kraus, N. C. (ed.), Coastal Sediments '87.

1353. Frish, Adam A., David A. Evans, J. P. Hudson and John D. Boon, III. 1987. Shape discrimination of sand samples using the fractal dimension. Pp. 138-153 *in* Magoon, O. T. et al. (eds.), Coastal Zone '87.

1354. Lynch, Maurice P. and Karen Kelly. 1987. Regional preparation of marine climate assessments: a case study in the Chesapeake Bay. Pp. 201-206 *in* Magoon, O. T. et al. (eds.), Coastal Zone '87.

1355. Catallo, William J., III, and R. P. Gambrell. 1987. The effects of high levels of polycyclic aromatic hydrocarbons on sediment physicochemical properties and benthic organisms in a polluted stream. Chemosphere 16:1053-1063.

1375. Andrews, Jay D. 1987. *Haplosporidium nelsoni* disease of American oysters. International Council for the Exploration of the Sea. Identification Leaflets for Diseases and Parasites of Fish and Shellfish. Leaflet no. 38.

1376. Andrews, Jay D. 1987. *Haplosporidium costale* disease of American oysters. International Council for the Exploration of the Sea. Identification Leaflets for Diseases and Parasites of Fish and Shellfish. Leaflet no. 39.

Annual Report

45. Forty-Fifth Annual Report for the Period Ending June 30, 1986

Data Report

26.Huzzey, L. M. and J. M. Brubaker. 1986. Hydrographic Data from the Wolftrap Section 1982-1983.

Marine Resources Advisory

31. Burreson, Gene, Al Kuo, and Roger Mann. Potential Effects of the 1986 Drought on the Oyster Industry of Virginia. 7 pp.

32. Burreson, Gene. Status of Major Oyster Diseases in Virginia, 10/86, 4 pp.

33. Burreson, Gene. Status of Major Oyster Diseases in Virginia, 7/87, 4 pp.

Special Reports in Applied Marine Science and Ocean Engineering

278. Unkulvasapaul, Yothin, Paul V. Hyer, and Albert Y. Kuo. 1986. Water Quality in a Virginia Potomac Embayment: Belmont-Occoquan Bay. 127 pp. + appendices.

279. Hyer, Paul V. and Albert Y. Kuo. 1987 revision. Water Quality in a Virginia Potomac Embayment: Neabsco Creek. 88 pp. + appendices

281. Silberhorn, Gene M. and Walter I. Priest, III. 1987. City of Norfolk Tidal Marsh Inventory. 54 pp.

282. Lucy, Jon and Eleanor Bochenek. 1986. Norfolk's Harborfest '86: A Tenth Anniversary Analysis. 68 pp.

283. Byrne, Robert J., Albert Y. Kuo, Roger L. Mann, John M. Brubaker, Evon P. Ruzecki, Paul V. Hyer, Robert J. Diaz, and John H. Posenau. 1986. New Port Island: An Evaluation of Potential Impacts on Marine Resources of the Lower James River and Hampton Roads. Volume 1 - Text,'276 pp Volume II-Appendices (in press), and Executive Summary. 28 pp.

292. Bradshaw, Julie G. and Albert Y. Kuo. 1987. Salinity Distribution in the James Estuary. 110 pp

Special Scientific Report

116. Kelly, Karen L. and Terry L. Bashore. 1986. Marine Environmental Assessment: Chesapeake Bay, December 1985-February 1986. 33 pp.

117. Bashore, Terry L. and Karen L. Kelly. 1987. Marine Environmental Assessment: Chesapeake Bay, March 1986-August 1986. 51 pp.

Manuscripts

Andrews, J. D. 1987. Use of Patent Tongs for Harvesting Oysters. 3 pp.

Virginia Institute of Marine Science. Dept. of Physical Oceanography and Environmental Engineering. 1985. Operation Manual for the VIMS Combined Hydrodynamic-Ecosystem Model (HEM). 156 pp.

Virginia Sea Grant College Program, Marine Resource Special Report

Whitcomb, James. 1986. Oyster Spatfall in Virginia Rivers: 1985 Annual Summary. 19 pp.

APPENDIX III

FINANCIAL MANAGEMENT AND ADMINISTRATION

The Institute experienced another year of growth as reflected by the cash expenditures for the fiscal year. The State funded activity increased from $8.9 million in 1986 to $9.6 million in 1987 or approximately 8%. The sponsored research activity also increased during the year from $2.9 million in 1986 to $3.3 million during 1987, or approximately 13%.

Management initiated two significant structural changes to the program organization of the Institute. The first change was the establishment of the Higher Education Program of Financial Assistance for Educational and General Services to identify sponsored research separately from State sponsored activity. Second, plans were made to establish properly the maximum employment level of the Institute.

The Institute initiated a major accounting software conversion program in conjunction with the College of William and Mary. The conversion, a year-long project, involved replacing the existing batch-driven Financial Accounting System (FAS) with an on-line query oriented Financial Reporting System (FRS) with enhanced reporting capability from the same software manufacturer. During the year, the conversion project team attended formal training sessions, reviewed existing systems for compatibility with FRS, designed and documented proposed and existing systems, and procured necessary equipment for on-line access to the system. The first phase of the conversion was completed with the system "going live" 1 July 1987 and providing basic accounting/budgetary information.

The financial records for the preceding fiscal year (1986) were audited by the Auditor of Public Accounts (APA). The Institute received an unqualified opinion from APA as well as management comments for improving internal control. The Internal Audit Office of the College of William and Mary reviewed the sponsored research revolving loan fund used to support contract expenditures until receipt of the billing from the sponsor. This loan program was proposed by the Institute and developed in cooperation with state's Department of Planning and Budget. The audit revealed no material deficiencies.

The fiscal year also brought to the Institute an $64,000 allocation from the Higher Education Equipment Trust Fund. This fund is designed to supplement an agency's yearly equipment expenditures in an effort to reestablish state-of-the-art equipment in higher education. In order to qualify for this fund, the Institute has to maintain and enhance the Fixed Asset Accounting System (FAACS), develop equipment priority lists, and subscribe to other administrative procedures. With the continuation of this program over the next five years, the Institute expects to enhance substantially its equipment inventories with much needed items.

APPENDIX IIIa

VIRGINIA INSTITUTE OF MARINE SCIENCE
CASH EXPENDITURES
Fiscal Year 1986-1987

Research	State Funds	Sponsored Research	Total
Program Area			
I. Investigate the fisheries of Virginia and factors affecting fluctuations in abundance.	$377,300	$162,900	$540,200
II. Investigate and define the distribution of benthic animals and communities and their interactions with the biological, physical and chemical environment.	54,500	241,200	295,700
III. Develop an understanding of plankton processes in the Chesapeake Bay system and Virginia coastal waters.	141,000	67,600	208,600
IV. Describe and evaluate the tidal fresh-water ecosystems of Virginia's major rivers.	44,500	-0-	44,500
V. Investigate structure and function of mesohaline marshes and submerged aquatic vegetation.	243,400	178,600	422,000
VI. Study diseases of marine and estuarine organisms.	90,500	119,500	210,000
VII. Develop and perfect methods and techniques for economical culture of marine and estuarine organisms.	347,600	32,500	380,100
VIII. Determine the fate and effect of toxic chemicals in the Chesapeake Bay system.	797,500	256,000	1,053,500
IX. Study nutrient cycling processes and controls in riverine, estuarine and coastal marine environments.	165,500	-0-	165,500
X. Evaluate factors leading to, and the consequences of, nutrient enrichment.	117,600	263,400	381,000
XI. Understand the dynamics of benthic boundary layers and associated processes of sediment resuspension, transport, and animal-sediment interaction on coastal and estuarine environments.	128,900	170,100	299,000

Research *Program Area*	State Funds	Sponsored Research	Total
XII. Describe and understand the circulation of waters in the estuarine and coastal environment.	531,100	44,400	575,500
XIII. Develop a better understanding of shoreface, surf zone and beach processes.	$ 50,900	$ 68,600	$ 119,500
XIV. Describe and explain the late Quaternary sedimentology, stratigraphy and geological evolution of the Chesapeake Bay and coastal waters.	70,500	164,900	235,400
XV. Conduct investigations related to the development, utilization, and management of resources of significance to the marine environment.	358,600	41,400	400,000
Total Research	$3,519,400	$1,811,100	$5,330,500
Monitoring *Program Area*			
I. Fisheries	$ 389,000	$ 675,800	$1,064,800
II. Plankton	68,000	26,800	94,800
III. Bacteria (Lower York River)	-0-	-0-	-0-
IV. Parasites and Pathogens	100	9,400	19,500
V. Benthic Invertebrates	17,200	-0-	17,200
VI. Estuarine Plant Communities	-0-	-0-	-0-
VII. Coastal Erosion	-0-	97,100	97,100
VIII. Physical and Chemical	85,500	11,000	96,500
Total Monitoring	$ 559,800	$ 830,100	$1,389,900
Miscellaneous	$ 138,500	$ 129,700	$ 268,200
Advisory Services	$ 220,700	$ 506,900	$ 727,600
Education	$ 676,800	-0-	$ 676,800
SUBTOTAL	$5,115,200	$3,277,800	$8,393,000
Support			
Research and Academic Administration	$1,389,600	$ -0-	$ 1,389,600
Service Centers	614,100	-0-	614,100
Financial Administration	1,459,600	-0-	1,459,600
Physical Plant	1,067,200	-0-	1,067,200
Total Support	$4,530,500	$ -0-	$ 4,530,500
GRAND TOTAL	$9,645,700	$3,277,800	$12,923,500

APPENDIX IIIb

GRANTS AND CONTRACTS AWARDED
July 1, 1986 - June 30, 1987

Federal Funding

Austin, Herbert and Mark Chittenden; "Chesapeake Bay Stock Assessment," $337,724, National Marine Fisheries Service. (7/1/86 - 6/30/88)

Boon, John, III; "Testing Datasonics Model ASA-920 Sonar Altimeter," $2,000, U. S. Army Corps of Engineers. (7/10/86 - 9/8/86)

Chu, Fu-Lin and Beverly Anne Weeks; "Investigation of Acquired Immunity Adaptive Response in the American Oyster," $35,247, Sea Grant/National Oceanic and Atmospheric Administration. (1/1/87-12/31/87)

Diaz, Robert J. and Linda Schaffner; "Baltimore Channels, Benthic Monitoring," $216,208, Baltimore Army Corps of Engineers. (5/17/87 - 5/17/88)

Diaz, Robert J.; "Equipment Funding for Low Dissolved Oxygen Studies," $5,590, Sea Grant/National Oceanic and Atmospheric Administration. (5/1/87 - 12/31/87)

DuPaul, William; "Marine Advisory Services," $421,006, Sea Grant/NOAA. (1/1/87 - 12/31/87)

DuPaul, William; "Sea Scallop Research," $9,135, Sea Grant/National Oceanic and Atmospheric Administration. (4/1/87 - 3/31/87)

Ellis, Lehman; "Cryopreservation of Commercially Important Marine Bivalves Gametes and Larvae," $29,181, Sea Grant/NOAA. (1/1/87 - 12/31/87)

Gammisch, Robert; "Side Scan Sonar of Artificial Reef Sites," $3,730, U.S. Fish and Wildlife Service. (8/8/86 - 8/8/87)

Hargis, William J., Jr.; "Fish Pathology Studies," $18,000, Sea Grant/National Oceanic and Atmospheric Administration. (3/1/87 - 12/31/87)

Hargis, William J., Jr.; "Histopathology of Eye Tissues of Indigenous Fish," $4,500, National Marine Fisheries Service. (8/19/86 - 10/31/86)

Hargis, William J., Jr.; "Ulcerative Disease Syndrome Committee," $735.00, Sea Grant/National Oceanic and Atmospheric Administration. (5/1/87 - 12/31/87)

Huggett, Robert J.; "TBT Analysis," $13,800, Department of the Navy, Weyher/Livesey. (3/15/87 - 9/30/87

Kator, Howard and Martha W. Rhodes; "Bacterial Counts in Shellfish Growing Area," $28,650, NOAA. (10/1/86 - 9/30/87)

Kimball, Suzette; "Interpersonnel Agreement," $8,536, Vicksburg Army Corps of Engineers. (4/30/87 - 4/30/88)

Lipcius, R. N.; "Interactive and Non-Linear Effects of Predation," $80,936, National Science Foundation. (4/1/87 - 9/30/89)

Loesch, Joseph G.; "Mark and Recapture Study of Striped Bass in the James River," $50,380, National Marine Fisheries Service. (5/1/87 - 4/30/88)

Loesch, Joseph, James Colvocoresses and William Kriete; "Striped Bass Abundance in Virginia," $119,568, National Marine Fisheries Service. (8/1/86 - 7/31/87)

Loesch, Joseph and William Kriete; "Assessment of Commercial Fishing Effort in Virginia," $26,600, National Marine Fisheries Services. (11/1/86 - 10/31/87)

Loesch, Joseph G. and William Kriete; "Striped Bass Stocking Experiment on the Pamunkey River," $27,316, U. S. Fish and Wildlife Service. (3/1/87 - 2/28/88)

Lucy, Jon; "Catch Trends in Offshore Recreational Fishery," $32,265, U.S. Fish and Wildlife Service. (8/8/86 - 8/8/87)

Lucy, Jon; "Evaluating Catch Data on Artificial Reefs," $23,920, U.S. Fish and Wildlife Service. (7/29/86 - 7/29/87)

MacIntyre, William G.; "Sorption, Organic Mixture Components," $35,000, Air Force Office of Sponsored Research. (6/1/87 - 5/31/88)

Mann, Roger; "Influence of Low Oxygen Tension on Oysters," $21,999, Sea Grant/National Oceanic and Atmospheric Administration. (9/1/86 - 12/31/87)

Meehan, Brian and Herbert Austin; "Stock Identification Using Electrophoretic Analysis," $202,805, U.S. Fish and Wildlife Service. (7/29/86 - 11/30/87)

Musick, John A; "Stock Identification, Flounder Mark and Recapture," $104,845, U.S. Fish and Wildlife Service. (8/8/86 - 10/30/87)

Nichols, Maynard and Robert J. Diaz; "Plume Monitoring of Rappahannock and York Spit Channels," $177,000, Baltimore Army Corps of Engineers. (4/07/87 - 12/31/88)

Neilson, Bruce; "Bay Monitoring," $240,114, Environmental Protection Agency. (10/1/86 - 11/30/87)

Norcross, Brenda and Herbert Austin; "Characterization of the Relationship between Seasonal Wind Regimes and the Recruitment of Croaker and Flounder," $19,082, Sea Grant/NOAA. (1/1/87 - 12/31/87)

Orth, Robert J.; "Distribution of Sub-Aquatic Vegetation," $6,000, NOAA. (10/1/86 - 9/30/87)

Orth, Robert J. and Jacques van Montfrans; "Value of Shallow Water Habitats for Early Stages of Blue Crab," $46,326, Sea Grant/NOAA. (1/1/87 - 12/31/87)

Schaffner, Linda; "REMOTS and Trawl Survey, Duck, North Carolina," $12,362, Army Corps of Engineers. (9/16/86 - 12/31/86)

Webb, Kenneth; "Is Phosphorous Removal an Efficient/Effective Chesapeake Bay Management Practice?," $45,000, NOAA. (10/1/86 - 9/30/87)

Wetzel, Richard; "Response and Stability of Eelgrass Communities in Chesapeake Bay," $22,326, Sea Grant/NOAA. (1/1/87 - 12/31/87).

Wright, L. D.; "Bed Response of Mid-Shoreface to Wind Events," $65,197, National Science Foundation. (1/15/87 - 12/31/88)

Commonwealth Funding

Bender, Michael; "Scotland Wharf Ferry Kepone Analysis," $1,409, Virginia Department of Highways. (5/15/87 - 8/31/87)

Bieri, Rudolf; "Pilot Toxics," $213,827, State Water Control Board. (11/1/86 - 6/30/88)

Boon, John; "Evaluation of Sediment Dynamics and the Mobility of Heavy Minerals," $23,635, Dept. of Mines, Minerals and Energy (Minerals Management Services). (3/1/87 - 12/31/88)

Diaz, Robert J.; "Evaluation of Benthic Resources Value of Impounded and Non-Impounded Tidal Creeks/Eastern Shore," $17,000, Soil and Water Commission. (12/1/86 - 6/30/87)

Hardaway, Scott; "Joint Commonwealth Programs Addressing Shore Erosion in Virginia," $95,780, Soil and Water Commission. (7/1/86 - 6/30/87)

Hardaway, Scott; "Virginia Breakwater Marsh Study," $3,511, Department of Conservation and Historic Resources. (4/1/87 - 6/30/87)

Hershner, Carl and Richard Wetzel; "Forested Buffer Zones," $32,957, Soil and Water Commission. (12/1/86 - 6/30/87).

Hobbs, Carl H., III; "Fossilized Oyster Shell, Pocomoke Sound," $33,625, Virginia Marine Resources Commission. (2/1/87 - 6/30/87)

Hobbs, Carl H. and R. Berquist; "Offshore Heavy Minerals Investigations," $118,581, Department of Mines, Minerals and Energy. (7/1/86 - 6/30/87)

Lawrence, Lee F.; "The Bay Team," $150,000, Council on the Environment. (7/1/86 - 6/30/88)

Lawrence, Lee F.; "Marine Science Mentorship Program," $4,924, Virginia Department of Education. (6/15/87 - 7/31/87)

Mann, Roger; "Chuckatuck Creek Survey," $3,500, Department of Highways and Transportation. (5/15/87 - 8/31/87)

Musick, John A.; "Ecology of Sea Turtles in Virginia," $53,000, Commission of Game and Inland Fisheries. (7/1/86 - 6/30/87)

Neilson, Bruce; "Buffer Zones, Marine Flushing," $90,000, Virginia Department of Health. (12/1/86 - 60/30/88)

Other Funding

Bender, Michael; "Analysis of Kepone Samples," $1,820, Virginia Power. (4/15/86 - 7/31/87)

Bender, Michael; "Kepone Analysis," $8,250, State Water Control Board. (7/1/86 - 6/30/87)

Bender, Michael; "Sample Analysis," $2,883, American Petroleum Institute. (8/1/86 - 8/31/86)

Bender, Michael; "Sediment Sample Analysis," $7,171, Maryland Department of Health. (7/1/86 - 11/30/86)

Bender, Michael; "Sample Analysis from Proposed Dredging Site on the James River," $975, Park 500. (9/15/86 - 10/15/86)

Bender, Michael; "Summer Research Aide Program," $12,000, Virginia Environmental Endowment. (1/1/87 - 9/30/88)

Diaz, Robert J. and Linda Schaffner; "Fowl River Benthic Profiling" $10,800, Taxonomic Associates. (5/15/87 - 12/31/87)

Diaz, Robert J.; "Marine Life Sampling," $6,862, Newport News Shipbuilding. (7/1/86 - 7/30/86)

Diaz, Robert J. and Linda Schaffner; "Sediment Profiling, Long Island Sound," $18,000, Evans and Hamilton. (5/15/87 - 12/31/87)

DuPaul, William; "Vessel Support Activities for the Mid-Atlantic Seafood Project," $17,922, Mid-Atlantic Seafood. (7/1/86 - 4/01/87)

Hershner, Carl and Jim Perry; "Endangered Plant Survey," $1,800, Virginia Natural Heritage Program. (5/27/87 - 11/30/88)

Huggett, Robert; "TBT International Conference," $10,000, The Johns Hopkins University. (10/1/86 - 10/31/86)

Kator, Howard; "Shellfish Pathogen Indicators," $31,496, Technion International, Inc. (7/7/86 - 9/30/87)

Kimball, Suzette; "Sand Resource Exploration," $51,240, City of Virginia Beach/Erosion Council. (6/15/87 - 6/15/88)

Lipcius, R. N.; "Experimental Ecology of Spiny Lobsters in the Mexican Caribbean," $12,535, State University of New York. (3/15/87 - 3/15/89)

Lipcius, R. N.; "Ecology of Juvenile Spiny Lobster and Conch at Lee Stocking Island-Bahamas," $8,600, Caribbean Marine Research Center. (1/1/87 - 12/31/87)

Lynch, Maurice P.; "Cooperative Agreement/Graduate Student," $9,274, Scientific Environmental Associates. (10/1/86 - 9/30/87)

Mason, Patrice; "Inspection of Styrofoam Samples," $1,800, Huntsman Chemical Corporation. (7/1/86 - TBA)

Musick, John A.; "Empress Study/Sea Turtle Census," $10,000, University of Maryland Center for Environmental and Estuarine Studies. (4/25/87 - 7/31/87)

Neilson, Bruce, L. D. Wright and R. J. Huggett; "Salt Pond Survey," $10,000, Southall Development. (6/1/87 - 12/31/87)

Roberts, Jr., Morris and Robert J. Diaz; "Historical Environmental Survey of Broad Creek, Norfolk, Virginia," $10,000, MMM Design Corporation. (3/5/87 - 8/31/8

Roberts, Jr., Morris; "TBT Bioassay," $50,000, The Johns Hopkins University. (9/1/86 - 3/31/87)

Silberhorn, Gene S.; "Remote Sensing Analysis of Coastal Wetlands in the Chesapeake Bay Region," $7,980, Martin Marietta. (8/8/86 - 11/7/86)

Theberge, N. Bartlett; "Erosion and Sediment Control Evaluation," $4,660, Smith, Demer and Norman, Inc. (11/1/86 -6/10/87)

Wright, L. D. and Betty Salley; "Sediment and Water Sample Analysis," $5,849, Alpine Seismic Corporation. (5/1/87 - 7/31/87)

APPENDIX IIIc

CONTINUING GRANTS AND CONTRACTS
July 1, 1986 - June 30, 1987

Federal Funding

Austin, Herbert, Mark Chittenden and James Colvocoresses; "Chesapeake Bay Stock Assessment," $258,000, National Oceanic and Atmospheric Administration. (7/1/85 - 6/30/87)

Austin, Herbert and James Colvocoresses; "Juvenile Fish Trawl Data Base," $19,568, National Oceanic and Atmospheric Administration/Council on the Environment. (1/1/86 - 12/31/86)

Burreson, Eugene; "Life Cycle Studies of Oyster Pathogens Using Enzyme Immunoassay Technique," $18,804, Sea Grant/NOAA. (1/1/86 - 3/31/86)

Chu, Fu-Lin; "Fatty Acids in the American Oyster," $90,000, National Science Foundation. (8/1/85 - 1/31/88)

Chu, Fu-Lin; "Investigation of Acquired Immunity Adaptive Response in the American Oyster," $35,644, Sea Grant/NOAA. (1/1/86 - 3/31/87)

Diaz, Robert J. and Linda Schaffner; "Dredging Studies Baltimore Harbor," $45,763, Army Corps of Engineers. (12/12/85 - 12/12/86)

Diaz, Robert; "Field Validation of a Benthic Microcosm System," $283,248, Environmental Protection Agency. (10/22/85 - 3/1/87)

DuPaul, William; "Sea Grant Marine Advisory Services," $443,142, Sea Grant/National Oceanic and Atmospheric Administration. (1/1/86- 3/31/87)

Ellis, Lehman; "Cryopreservation of Commercially Important Marine Bivalve Gametes and Larvae," $29,906, Sea Grant/NOAA. (1/1/86 - 12/31/86)

Haas, Leonard; "Saline Waters, Review and Historic Analysis," $36,000, Sea Grant/NOAA. (7/1/85 - 3/31/87)

Hargis, William J., Jr.; "Ulcer Disease Project," $1,000, Sea Grant/NOAA. (5/1/86 - 12/31/86)

Hobbs, III, Carl; "Resources of Fossil Shell, Rappahannock River," $21,533, Sea Grant/NOAA. (1/1/86 - 12/31/86)

Huggett, Robert; "Bay Monitoring/Sediment," $7,930, Environmental Protection Agency/State Water Control Board. (1/1/86 - 11/30/87)

Kator, Howard; "Shellfish Workshop," $10,000, Sea Grant/NOAA. (1/1/86 - 12/31/86)

Kator, Howard and Martha W. Rhodes; "Relayed Shellfish in the Lower Bay," $11,000, Sea Grant/NOAA. (1/1/86 - 12/31/86)

Kator, Howard and Martha W. Rhodes; "Evaluation of Containerized Relaying in Hard Clams," $47,886, Sea Grant/NOAA. (1/1/86 - 12/31/86)

Loesch, Joseph and William Kriete; "Assessment of the Commercial Fishing Effort in Virginia," $19,993, NOAA/Virginia Marine Resource Commission. (11/1/85 - 10/31/86)

Loesch, Joseph G.; "Alosa Stock Composition," $70,000, National Marine Fisheries Service. (5/15/86 - 6/31/87)

Loesch, Joseph G.; "Study of Alosa Stock Composition and Year Class Strength in Virginia," $89,700, National Marine Fisheries Service. (2/14/85 - 9/30/86)

Loesch, Joseph G. and J. Colvocoresses; "Study of Striped Bass/Commercial and Juvenile Abundance," $121,600, National Marine Fisheries Service. (10/1/84 - 9/30/86)

Lynch, Maurice; "Site Selection: National Estuarine Sanctuary," $10,000, National Oceanic and Atmospheric Administration. (8/1/85 - 2/28/86)

MacIntyre, William G.; "Sorption of Organic Mixture Components," $60,000, Air Force, Office of Sponsored Research. (6/1/86 - 5/31/87)

Mann, Roger; "Influence of Low Oxygen Tensions on Larvae," $20,000, Sea Grant/NOAA. (7/1/85 - 12/31/86)

Mason, Patrice; "TEM Studies," $10,000, National Aeronautics and Space Administration/William and Mary. (9/15/85 - 3/31/87)

Musick, John; "A Summary of Lift and Drag and Related Drag Reducing Mechanism in Fishes," $20,000, NASA. (11/84 - 10/87)

Neilson, Bruce; "Bay Monitoring/Water," $174,928, Environmental Protection Agency/State Water Control Board. (1/1/86 - 11/30/86)

Norcross, Brenda; "Seasonal Recruitment of Croaker and Flounder," $18,923, Sea Grant/NOAA. (6/1/86 - 6/30/87)

Olney, John; "Biological Relevance of Patterns of Larval Fish," $110,000, National Science Foundation. (4/85 - 6/87)

Olney, John and Bruce Comyns; "Predators and Striped Bass Eggs and Larvae," $70,496, Fish and Wildlife Service. (4/22/85 - 10/22/86)

Orth, Robert J.; "Distribution and Abundance of Sub-Aquatic Vegetation," $59,410, Environmental Protection Agency/State Water Control Board. (6/1/86 - 4/15/87)

Orth, Robert J.; "Mapping of Submerged Aquatic Vegetation," $25,000, Fish and Wildlife Service. (8/16/85 - 8/15/86)

Orth, Robert J. and Jacques van Montfrans; "The Role and Value of Shallow Water Habitats," $41,548, Sea Grant/NOAA. (1/1/86 - 3/31/87)

Webb, Kenneth; "Is Phosphorus Removal an Efficient/Effective Chesapeake Management Practice?," $55,000, NOAA/Council on the Environment. (10/1/85 - 9/30/86)

Weeks, B. A. and J. Ernest Warinner; "The Effects of Environmental Pollutants on the Cellular Immune Response of Fish," $13,626, Sea Grant/NOAA. (1/1/86 - 12/31/86)

Commonwealth Funding

Defur, Paul; "Development of Advanced Toxic Analysis, Detection System and Data Base," $198,605, State Water Control Board. (2/1/85 - 12/31/86)

Defur, Paul; "Tributary Sediment Organics," $13,640, SWCB. (4/1/86 - 11/30/86)

DuPaul, William; "Continuing Education and Information Transfer in Innovative Technology," $21,317, Center for Innovative Technology. (3/1/86 - 2/28/87)

Grulich, Ron; "Development of Economic Data Base for Describing Virginia's Commercial Harvest Sector," $9,000, Council on the Environment. (5/1/85 - 11/1/86)

Hobbs, III, Carl; "Assessment of Economic Heavy Minerals," $40,000, Virginia Division of Mineral Resources. (4/1/86 - 12/31/87)

Lawrence, Lee; "Marine Science Mentorship," $4,418, Virginia Department of Education. (6/10/86 - 7/31/86)

Musick, John A.; "Mortalities, Activities, Behavior, and Migratory Pathways of Sea Turtles in Virginia," $52,000, Virginia Game and Inland Fisheries. (6/26/85 - 12/31/86)

Wright, L. D.; "Side-scan Sonar Survey of Artificial Reef Sites," $7,074, Va. Marine Resources Commission. (10/1/85 - 12/31/85)

Other Funding

Barrick, Susan; "Update and Maintain Chesapeake Bay Bibliography," $25,000, Maryland Department of Natural Resources. (6/85 - 11/87)

Byrne, Robert; "Newport Island Evaluation," $238,347, Peninsula Ports Authority. (7/1/85 - 11/30/86)

Cerco, Carl; "Evaluation of Sediment Oxygen Demand, Upper Potomac Estuary," $45,550, Hydroqual. (6/10/86 - 12/31/86)

Diaz, Robert J. and Linda Schaffner; "Fowl River Benthic Profiling," $50,995, Taxonomic Associates. (6/1/85 - 12/31/87)

Ellis, Lehman; "Establishment of Oyster Cell Lines," $35,000, Jeffress Memorial Trust. (1/1/86 - 12/31/88)

Huggett, Robert; "TBT Monitoring," $50,000, Trust, The Johns Hopkins University. (5/13/86 - 10/31/86)

Kuo, Albert and Carl Cerco; "Model Studies: Sediment Oxygen Demand, Pagan River," $6,000, Guy and Davis. (6/12/86 - 10/31/86)

Lawrence, Lee; "Chesapeake Bay Related Teaching Materials," $6,000, Virginia Research Education Council. (6/1/86 - 12/31/86)

Lynch, Maurice; "Cooperative Agreement with Chesapeake Research Consortium," $40,715, Chesapeake Research Consortium. (10/1/85 - 9/30/86)

Lynch, Maurice; "Cooperative Research Education," $9,200, Scientific Environmental Associates. (9/1/85 - 9/30/86)

Mann, Roger; "Metamorphosis in Wood-Boring Molluscs," $32,175, Woods Hole Oceanographic Institution/Office of Naval Research. (2/15/85 - 8/86)

Musick, John A.; "Empress Study Sea Turtle Census," $99,995, University of Maryland Center for Environmental and Estuarine Studies. (4/25/86 - 4/24/87)

Neilson, Bruce; "Pagan River Benthic Oxygen Demand," $3,350, Guy and Davis. (7/12/85 - 12/31/85)

Neilson, Bruce; "Evaluation of Ware Creek," $35,938, James City County. (6/10/86 - 9/9/86)

Orth, Robert J.; "Distribution of Sub-Aquatic Vegetation," $11,625, Philadelphia Academy of Sciences. (7/1/85 - 3/31/87)

Thoney, Dennis; "Humoral Immunological Response of Spot," $400, Lerner Gray Fund of the American Museum of Natural History. (5/21/86 - 3/31/87)

Wright, L. D. and Robert Gammisch; "Mud Underflow Dynamics II," $54,379, Louisiana State University. (3/1/86 - 60/30/87)

APPENDIX IV

VIMS SEMINAR SUMMARY
July 1, 1986 - June 30, 1987

The VIMS Seminar Program promotes and encourages the presentation of formal and informal seminars by distinguished colleagues from other institutions in the United States and abroad. The program contributes to an informed community of scholars by facilitating communication between faculty, staff and students of the School of Marine Science and the national and international community of marine scientists. To perform this function a Seminar Committee receives requests for seminar speakers from the VIMS staff and student body; distributes announcements of scheduled speakers to a large mailing list including several Faculties of the College of William and Mary as well as neighboring institutions; and provides logistic support and honoraria or travel reimbursement for scheduled seminarians.

During the period July 1, 1986 - June 30, 1987 the Seminar Committee presented an active and well-attended program including 38 speakers from 33 institutions. Twelve overseas organizations were part of this varied schedule including scientists from Brazil, India, Australia and Demark. In addition, 42 members of the VIMS staff and student body presented reports of their research. In all, the committee recorded 84 seminars. A detailed listing of speakers, affiliations, dates and abbreviated seminar titles is appended.

In addition, the Graduate Student Association sponsors two seminar series to promote interaction and communication among members of the VIMS community.

The Faculty Seminar Series, which is held once a month during the academic year, is a forum under which the faculty can keep the rest of the VIMS community up-to-date on their recent research.

Name	Date	Title
Dr. Richard Winn College of Virgin Islands St. Thomas, Virgin Islands	7/1/86	Comparative Ecology of three *Cancer* sp. crabs in Southern California
Dr. Arunthavarani Thiyagarajah West Virginia University Morgantown, West Virginia	7/11/86	Histopathological Assessment of the Xenobiotics in Fish Tissues in Virginia
Mr. C. R. Berquist VIMS Graduate Student	7/14/86	Stratigraphy and Heavy Mineral Analysis in the Lower Chesapeake Bay, Virginia
Mr. Robert Gammisch VIMS Graduate Student	7/15/86	Geological History of a Holocene Drainage System, Hack Creek, VA
Dr. Ralph Elston Battelle, N. W. Lab. Sequim, Washington	7/16/86	Shellfish Diseases in the Pacific North West - An Update
Dr. D. J. Staples CSIRO Marine Lab Queensland 4163 Australia	7/16/86	Penaeid Prawn Recruitment Research of the CSIRO Marine Laboratories, Australia
Ms. Pat Duncan VIMS Graduate Student	7/28/86	The Use of Crab Meal as a Supplemental Food for the Juvenile Hard Clams, *Mercenaria mercenaria*

Mr. Thomas Sminkey VIMS Graduate Student	8/4/86	The Morphology and Function of the Pharyngeal Sac in Two Stromateid Fishes, *Peprilus triachanthus* and *P. paru*
Mr. Clifford Ryer VIMS Graduate Student	8/6/86	Towards an Optimal Foraging Model for the Northern Pipefish
Dr. Mark Luckenbach VIMS	8/6/86	A Review of Processes Affecting Larval Recruitment in Marine vs. Freshwater Habitats
Mr. Steven M. Atran VIMS Graduate Student	8/7/86	Weekly Fluctuations in the Catchability Coefficient of Atlantic Menhaden, 1968-1982
Dr. George A. Janauer Wien, Austria	8/15/86	Flow and Light in Submersed Macrophyte Communities
Mr. Robert T. Ray VIMS Graduate Student	8/22/86	The Role of Picoplankton in Phytoplankton Dynamics of a Temperate Coastal Plain Estuary
Dr. Carl Hershner VIMS	9/10/86	Tidal Wetlands Research Activities
Dr. A. Rajaguru Portonovo, India	9/11/86	Marine Mammals of India: Whales, Dolphins, Dugongs and Sea Otters
Dr. Hallett (Bud) Harris Ms. Vickie Harris University of Wisconsin Green Bay, Wisconsin	9/22/86	Incorporating Scientific Information into the Resource Management Problems of Green Bay, Wisconsin
Dr. Ashok Desphande Dr. Roger Mann Dr. Robert Orth VIMS	9/26/86	Three Views of India: Slides and Discussion
Dr. Christopher Langton Oregon State University Newport, Oregon	10/6/86	Microcapsules, Molluscs and Man
Dr. Fu-Lin Chu VIMS	10/15/86	The Studies of Acquired Immunity and metabolism of Dietary Fatty Acids in Oysters
Mr. Peter Wilcock Massachusetts Institute of Technology Cambridge, Massachusetts	10/21/86	Bed-Load Transport of Mixed Size Sediment
Ms. Linda Huzzey VIMS	10/23/86	Lateral Variability in a Coastal Plain Estuary
Dr. John M. Hamrick University of Virginia Charlottesville, Virginia	10/24/86	Lagrangian Circulation and Mass Transport in Estuaries
Dr. Jens Borum University of Copenhagen Copenhagen, Denmark	10/24/86	The Effect of Nutrient Enrichment on Total Primary Production and Balance Among Different Autotrophic Components in Shallow Marine Areas

Dr. Jerome P.-Y Maa University of Florida Gainesville, Florida	10/28/86	Erosion of Soft Mud by Waves
Dr. Jens Borum University of Copenhagen Copenhagen, Denmark	10/29/86	Dynamics of Epiphytic Algae on Eelgrass Leaves
Mr. Tom Munroe VIMS Graduate Student	10/31/86	Memoirs of Ichthyology's Resident Iceptor
Dr. Labbish Chao University of Rio Grande, Brazil	11/6/86	Synopsis of Zoogeography of Sciaenid Fishes
Dr. Mohamed A. Abdelrhman Memorial University St. John's, Newfoundland	11/7/86	Pattern Recognition of Suspended Sediment and Velocity Profiles in the Benthic Boundary Layer
Dr. Antonio J. Figueras Rutgers University Port Norris, New Jersey	11/12/86	Parasites and Diseases of Mussels and Oysters in Spain
Dr. Robert J. Orth VIMS	11/12/86	An Overview of VIMS SAV Research Program
Ms. Jane DiCosimo VIMS Graduate Student	11/12/86	Biological Review and Commercial Fisheries Analysis of *Busycon carica* with Comments on *B. canaliculatum* and *B. contrarium*
Dr. John J. Stegeman Woods Hole Oceanographic Institution Woods Hole, Massachusetts	11/13/86	Cytochromes P-450 in Fish: Functional Aspects and Regulation of Xenobiotic and Steroid Metabolism
Dr. William Dennison SUNY, Stony Brook, New York	11/14/86	Factors Affecting Eelgrass Production
Mr. Steven M. Smith VIMS Graduate Student	11/19/86	Reproductive Ecology, Population Dynamics and Seasonal Movements of the Hogchoker, *Trinectes maculatus* in the Elizabeth River, VA
Mr. Joseph T. DeAlteris VIMS Graduate Student	11/21/86	Geomorphic History and Sedimentary Processes of Wreck Shoal, an Oyster Reef of the James River, Virginia
Ms. Maura Jansen VIMS Graduate Student	11/26/86	Parasites of Summer Flounder, *Paralichthys dentatus*, in the Chesapeake Bay
Dr. Denise Brightberg Benedict Estuarine Lab Benedict, Maryland	12/4/86	Interspecific Competition and the Abundance of Nest Sites: Factors Affecting Sexual Selection in a Temperate Goby
Mr. Glenn DeLaney VIMS Graduate Student	12/5/86	Morphometric and Meristic Stock Identification of summer flounder *Paralichthys dentatus*

Miscellanea Ichthyologicae	**2/8/86**	**Including the following:**
Mr. Tom Munroe VIMS Graduate Student		A Systematic Revision of Atlantic Tonguefish *Symphurus:* Cynoglossidae: Pleurnectiformes with a Preliminary Hypothesis of Species-Group Relationships
Mr. Michael Weinstein Lawler, Matusky & Skelly Eng. Pearl River, New York		Habitat Evaluation of Nekton Communities Inhabiting Temperate Salt Marshes and Seagrass Beds: an Overview
Dr. Bruce Collette NMFS Systematics Lab Washington, D. C.		The Stability of Classifications and Phylogenetic Uncertainty: Scombroidei, Case Study.
Mr. Robert Middleton VIMS Graduate Student		The Seasonal and Diel Use by Finfishes of a Mesohaline Intertidal Creek on the York River, Virginia
Dr. Tony Hawkins Plymouth, United Kingdom	12/8/86	Physiological Consequences of Genotype Mann Dependent Protein Turnover in *Mytilus edulus*
Dr. Bruce Neilson VIMS	12/10/86	Nutrient Enrichment Problems in Chesapeake Bay: Fact or Fiction
Dr. Gene Burreson Mr. Dennis Thoney VIMS	12/12/86	A Naturalist's View of Down Under
Mr. Bruce Comyns VIMS Graduate Student	12/15/86	Identification and Distribution of Urophysic (Gill, 1863) and Physic (Artedi, 1792) Larvae & Pelagic Juvenile in the Middle Atlantic Bight
Dr. Victor Hutchinson University of Oklahoma Norman, Oklahoma	12/17/86	Magnetism and Magnetic Orientation in Animals
Dr. David Goodrich NOAA, Washington, D.C.	12/19/86	Measurement of Estuary-shelf Exchange from Tide Records, with Implications for Larval Recruitment in the Chesapeake Bay
Dr. Mario Vieira SUNY, Stony Brook, New York	1/8/87	Applying Numerical Models to Estuarine Problems
Dr. James O'Donnell University of Cambridge Cambridge, England	1/15/87	A Numerical Model of a Frontally Bounded River Plume
Dr. Michael J. Dykstra School of Veterinary Medicine North Carolina State University Raleigh, North Carolina	1/20/87	Ulcerative Mycosis, a New Disease of of Estuarine Fish on the Atlantic Coast
Dr. Michael Vecchione NMFS Systematics Lab Smithsonian Institution Washington, D. C.	1/30/87	*In situ* Observations on the Early Life History of Squids in the Gulf of Mexico

Dr. Peter Baines Victoria, Australia	2/20/87	Influence of Bottom Topography on Stratified Flows
Collective seminars by VIMS faculty and students	**3/5/87**	**Including the following:**
Mr. Jacques van Montfrans		Substrate Choice by Blue Crab Megalopae and First Stage Juveniles
Mr. Clifford Ryer		Predation by Pipefish Upon Amphipods, and the Influence of Habitat Complexity: A Mechanistic Approach
Mr. Eugene Olmi		Recruitment of the Blue Crab in Open and Impounded Marsh Systems in South Carolina
Dr. Mark Luckenbach		Field Evidence for Tidally-mediated Foraging Strategies in a Surface Deposit Feeder
Dr. Romuald Lipcius		Complex Interactions and Factor Effects in Soft-bottom Predator-prey Complex
Ms. Randa Mansour		Habitat Selection and Agonistic Behavior of Two Sympatric Species of Crab, *Cancer irroratus* and *Carcinus maenas*
Dr. Jonathan Grant Dalhousie University Nova Scotia, Canada	3/9/87	Sediment Resuspension and the Growth of Bivalves
Dr. Steven Otwell University of Florida Gainsville, Florida	3/20/87	Emerging Fishery for Yellowfin Tuna in the South Atlantic and Gulf of Mexico
Dr. Leonard Muscatine University of California Los Angeles, California	3/20/87	Symbiotic Algae: Junk Food for Reef Corals
Mr. David Gussman VIMS Graduate Student	3/27/87	The Use of Brewery Waste in Shellfish Mariculture
Ms. Karen Mayne U. S. Fish and Wildlife Service Gloucester Point, Virginia	3/30/87	Larval Fish Ecology: A Critical Management
Ms. Linda Schaffner VIMS Graduate Student	4/1/87	Ecology of Benthos of the Lower Chesapeake Bay
Dr. Richard Tinsley University of London London, England	4/10/87	Host Parasite Coevolution in Amphibians
Dr. Brian Bradley University of Maryland College Park, Maryland	4/13/87	Stress as an Indicator of Pollution Hazard

Dr. Michael Sieracki VIMS	4/17/87	Color Image Analysis for Sizing and Classifying Nanoplankton Cells
Mr. Brian Keith Fowler VIMS Graduate Student	4/20/87	Primary Production and Temporal Variation in the Macrophytic Community of a Tidal Freshwater Swamp
Mr. William L. Matthews, III VIMS	4/27/87	The Del Norte Navigation System: A New Review and Status Report
Mr. Joseph Boyer VIMS Graduate Student	4/30/87	From Crab Shells to *Corella:* Why we aren't Up to Our Ears in Chitin
Dr. Des Connell SUNY, Stony Brook, New York	4/30/87	Bioaccumulation of Lipophilic Chemicals by Aquatic Biota
Mr. Robin vanTine VIMS Graduate Student	5/4/87	Aspects of the Ecology of Estuarine Light with Special Reference to Seagrasses in the Chesapeake Bay: Measurement and Models
Mr. J. Robert Woolsey University of Mississippi University, Mississippi	5/4/87	Exploration for Heavy Minerals Offshore of the Southeastern United States
Mr. Harry D. Johnson, Jr. VIMS Graduate Student	5/7/87	Predatory Potential of the Lobate Ctenophore, *Mnemiopsis leidyi*, on Planktonic Fish Eggs at the Mouth of the Chesapeake Bay
Dr. Labbish Chao J. Vieira L. Barbieri C. Montero VIMS Graduate Students	5/12/87	Bio-Ecology of Estuarine Fishes of Lagoa dos Patos and its Adjacent Regions, Southern Brazil
Dr. William Fisher The University of Maryland College Park, Maryland	6/4/87	Oyster Aquaculture and Disease Research in France
Dr. Gary A. Zarillo SUNY, Stony Brook, New York	6/12/87	Prediction of Hydrodynamics and Sediment of Tidally Dominated Environments
Dr. M. J. Waldock Burnham-On-Crouch Essex, England	6/17/87	Tributyltin (TBT) Research in the United United Kingdom
Dr. Robert Whitlatch University of Connecticut Storrs, Connecticut	6/25/87	*In situ* Studies on the Feeding Ecology of Deep-sea Organisms

APPENDIX V

VIMS ASSOCIATES

The VIMS Associates provides an avenue for private individuals and organizations interested in preserving the quality of the marine environment to support the work performed at the Virginia Institute of Marine Science. Through their gifts the members of the Associates play an active role in continuing the vitality of the Institute and advancing its service to the Commonwealth of Virginia and the nation.

The faculty, staff and students gratefully recognize the generous support of the following individuals and organizations during 1986-1987.

FOUNDERS' SOCIETY

Mr. A. Marshall Acuff, Jr. (c)
New York, New York

Mr. James A. Albano, Sr.
Norfolk, Virginia

Allied-Signal Corporation (c)
Petersburg, Virginia

Amoco Foundation, Inc. (c)
Chicago, Illinois

Mr. & Mrs. Robert F. Boyd (c)
Virginia Beach, Virginia

Mr. James Brewitt
Hayes, Virginia

Captain John W. Bunting,
USN (Ret.) (c)
Virginia Beach, Virginia
(Honorary Lifetime Member)

F/V CAROLINA CLIPPER (c)
Wells Scallop Company
Seaford, Virginia

Mr. & Mrs. Eugene A. Cervi
Yorktown, Virginia

Chesapeake Bay Yacht Clubs Association
McLean, Virginia

Chesapeake Corporation (c)
West Point, Virginia

Colonna's Shipyard, Inc.
Norfolk, Virginia

Dr. & Mrs. Crile Crisler (c)
Norfolk, Virginia

Mr. C. A. Cutchins, III (c)
Norfolk, Virginia

The Daily Press, Inc. (c)
Newport News, Virginia

Deltaville Fishing & Conservation Club
Deltaville, Virginia

The Edmondson Foundation (c)
Virginia Beach, Virginia

(c) charter member

Exxon Education Foundation
New York, New York

Dr. C. S. Fang
Newport News, Virginia

Mr. Peter L. Foley
Gloucester Point, Virginia
(Honorary Lifetime Member)

Ms. Barbara Forst
Gloucester, Virginia

The Flagship Group, Ltd. (c)
Norfolk, Virginia

Mr. B. Roland Freasier, Jr. (c)
Richmond, Virginia
(Honorary Lifetime Member)

Mr. Lewis L. Glucksman (c)
New York, New York
(Honorary Lifetime Member)

Mrs. Roberta Haines
Hampton, Virginia

Dr. & Mrs. William J. Hargis, Jr.
Seaford, Virginia

Dr. Robert Hutton
Mt. Solon, Virginia

Japan Fisheries Association
Washington, D.C.

The Jonathan Corporation (c)
Norfolk, Virginia

Mr. David T. Kanazawa
Kensington, Maryland

The Massey Foundation (c)
Richmond, Virginia

Metro Machine Corporation
Norfolk, Virginia

J. H. Miles & Company
Norfolk, Virginia

Newport News Shipbuilding &
Dry Dock Co.
Newport News, Virginia

Norfolk Shipbuilding & Drydock
Corporation (c)
Norfolk, Virginia

Mr. Moses D. Nunnally, Jr.
Richmond, Virginia

Ocean Mining Associates (c)
Gloucester Point, Virginia

Dr. Pierre C. Oustinoff
Williamsburg, Virginia

Mr. & Mrs. Julian A. Penello (c)
Portsmouth, Virginia

Mr. & Mrs. George W. Roper, II (c)
Norfolk, Virginia

Sovran Bank, N.A. (c)
Norfolk, Virginia

Tudor Marine, Inc. (c)
Norfolk, Virginia

Dr. Donna D. Turgeon
Fairfax Station, Virginia

Mr. William A. Van Engel
Gloucester Point, Virginia
(Honorary Lifetime Member)

Mr. Raymond T. Waller (c)
Richmond, Virginia

Dr. James C. Wright (c)
Virginia Beach, Virginia

Anonymous (1)

SUSTAINING MEMBERS

Ballard Fish & Oyster Co., Inc. (c)
Dr. Robert J. Byrne
Dr. & Mrs. J. A. Musick

SUPPORTING MEMBERS

Mr. Robert P. Albergotti, Jr.
Mr. & Mrs. Gary L. Anderson
Ms. Susan Barrick
Dr. Michael E. Bender
Dr. & Mrs. John D. Boon, III
Mr. John G. Brokaw

Dr. & Mrs. Robert J. Byrne
Dr. Mark E. Chittenden, Jr.
Mr. Hartwell Davis
Mr. & Mrs. John Entwisle
Ms. Ellen Fisher
Dr. Richard France
Mr. & Mrs. Dexter Haven
Mr. Bryan P. Hogge
Mr. & Mrs. A. H. Humphreys, Jr.
Mr. & Mrs. Earl Kelz
Dr. Albert Y. Kuo
Mr. Ernest C. Ladd
Ms. Fwu-Ding Lin
Dr. Maurice P. Lynch
Mr. & Mrs. George A. McKray
Mr. George Alexander McKray
Mr. Charles J. Natale, Jr.
Dr. Bruce J. Neilson
Dr. Polly A. Penhale
Mr. George Pongonis
Mr. Bruce H. Robison
Mrs. Linda C. Schaffner
Ms. Eileen L. Shea
Dr. Gene M. Silberhorn
Mr. Jerome P. Sovich
The Ukrop Foundation
Virginia Tech Foundation, Inc.
Ms. Anne Rooney Walker
Mr. James P. Whitcomb
Dr. L. D. Wright

Anonymous (1)

MEMBERS

Mr. Kenneth W. Able
Mr. Steven Atran
Mr. & Mrs. Thomas A. Barnard, Jr.
Ms. Julie G. Bradshaw
Mr. David R. Burris
Mrs. Mary H. Causey
Dr. Fu-Lin Chu
Ms. Angela M. D'Amico
Mr. John Dayton
Mr. & Mrs. Selden C. Dickinson
Dr. & Mrs. William D. DuPaul
Dr. Morty Eckhause
Mr. Michael S. Fedosh
Dr. Kenneth Finkelstein
Mr. Daniel J. Fisher
Mr. Gary D. Frazer
Mr. & Mrs. Lowell Fritz
Ms. Carol Furman
Mr. Richard A. Garfield
Dr. Richard A. Gleeson
Dr. George C. Grant
Mr. Malcom Green
Dr. Ming-Shan Ho
Mr. Carl H. Hobbs, III
Mr. & Mrs. Mohammed S. Huq
Mr. Paul V. Koehly
Mr. & Mrs. James L. Lake
Drs. James & Hope Lanier
Mr. George Lapointe
Mr. David F. Ludwig
Mr. Robert J. Lukens
M. Price Distributing
Mr. & Mrs. George Mapp
Ms. Karen L. McDonald
Ms. Janice Meadows
Dr. Winston R. Menzel
Dr. Robert W. Middleton
Mr. Martin L. Mitchel
Ms. Mary Mittiga
Ms. Hilary Neckles
Mr. Michael J. Oesterling
Mrs. Martha W. Rhodes
Mr. & Mrs. Peter S. Rosen
Mr. George G. Rountree
Dr. Paul A. Sandifer
Mr. & Mrs. Elmer J. Schaefer
Mr. A. K. Scribner, Jr.
Dr. Craig L. Smith
Ms. Donna J. Smith
Mr. & Mrs. George Thomas
Drs. Kenneth & Donna Turgeon
Mr. John J. Vaccaro
Ms. Diane Walker
Mr. J. Ernest Warinner, III
Ms. Sandra Thornton Whitehouse
Mr. W. Stanley Wilson
Ms. Cathy J. Womack

Anonymous (1)

OTHER

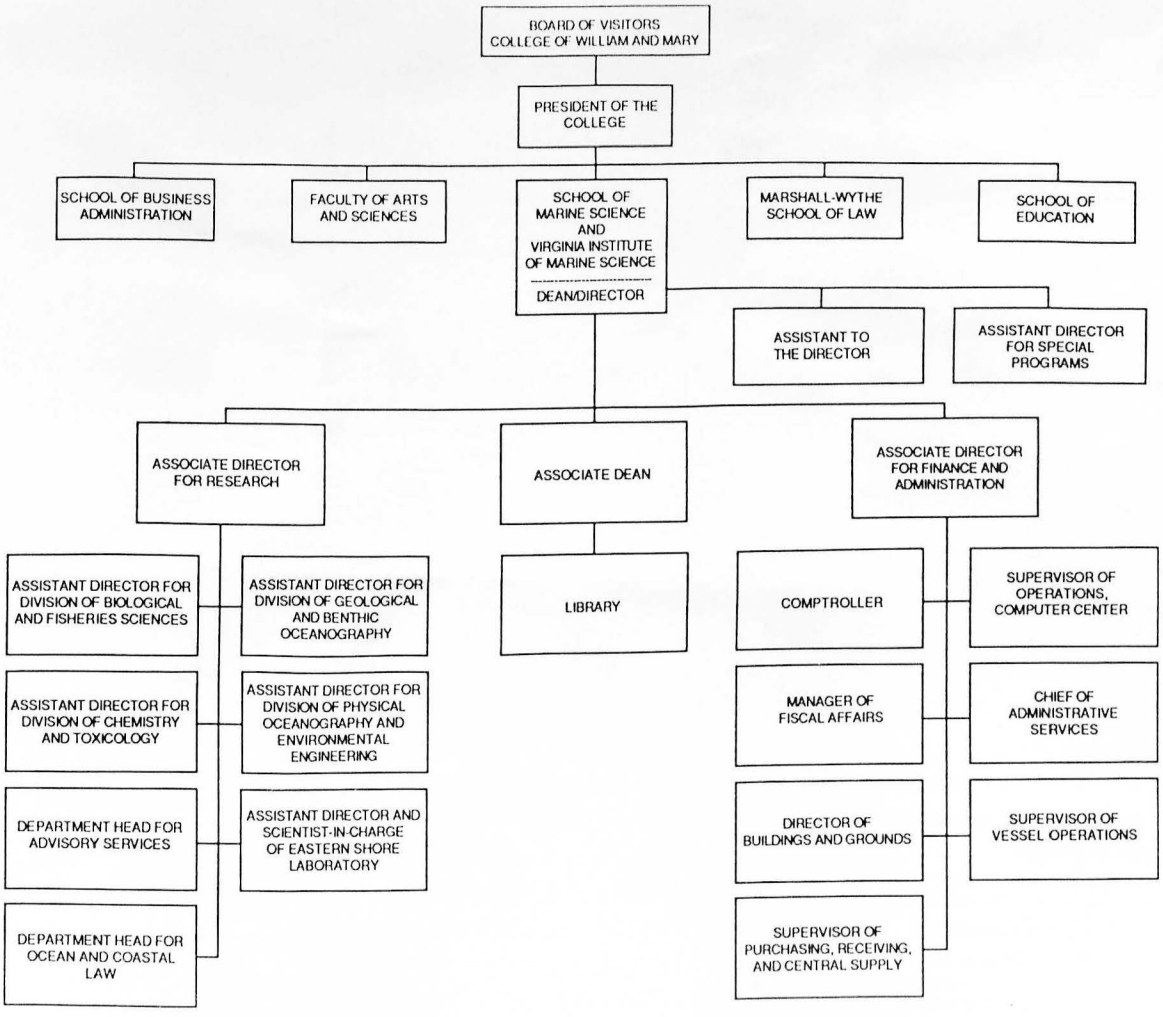
Mr. Dennis Cassada
Mr. Evangelos A. Voudrias
Mr. Scott Walker
Dr. Richard Wetzel

APPENDIX VI

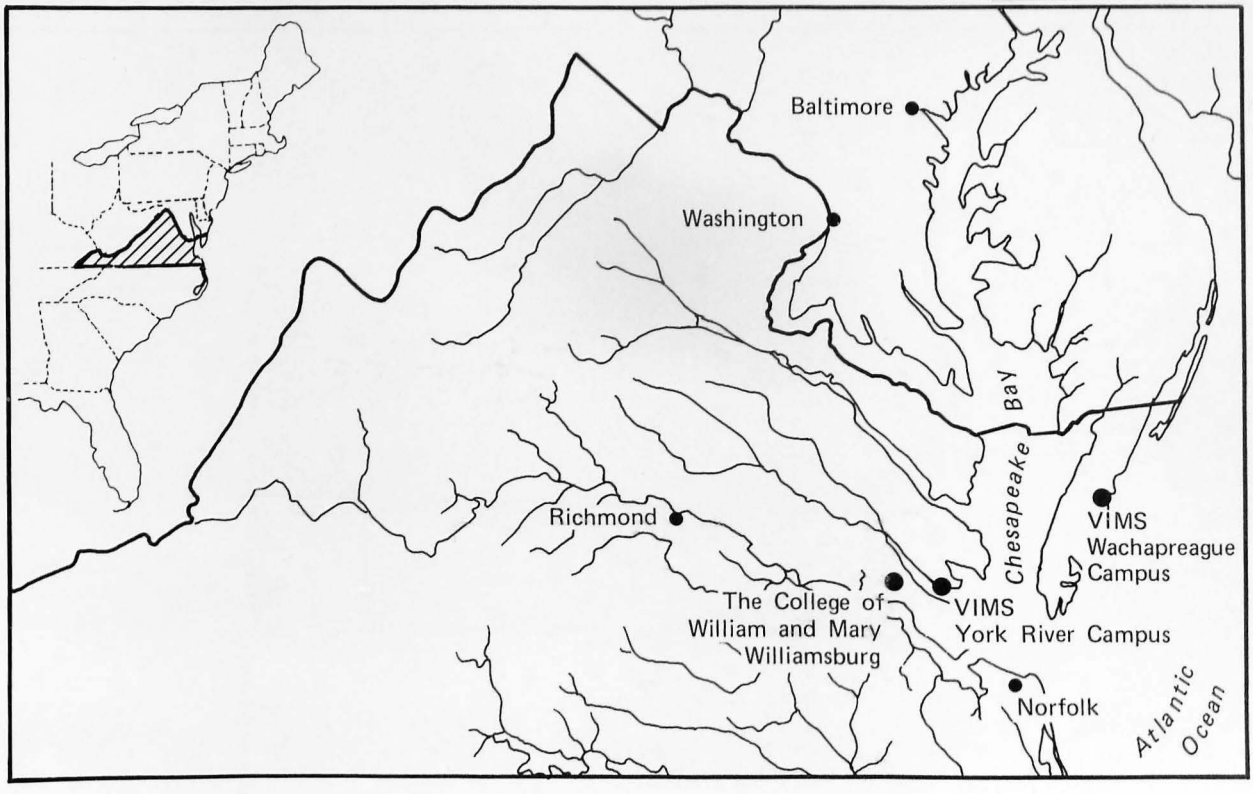
ORGANIZATION

The Virginia Institute of Marine Science/School of Marine Science under the direction of the Dean/Director is organized to fulfill its triple mission of research, education and advisory services. The institutional organization reflects an emphasis on research and the provision of timely advice on matters related to utilization of the Commonwealth's marine resources.

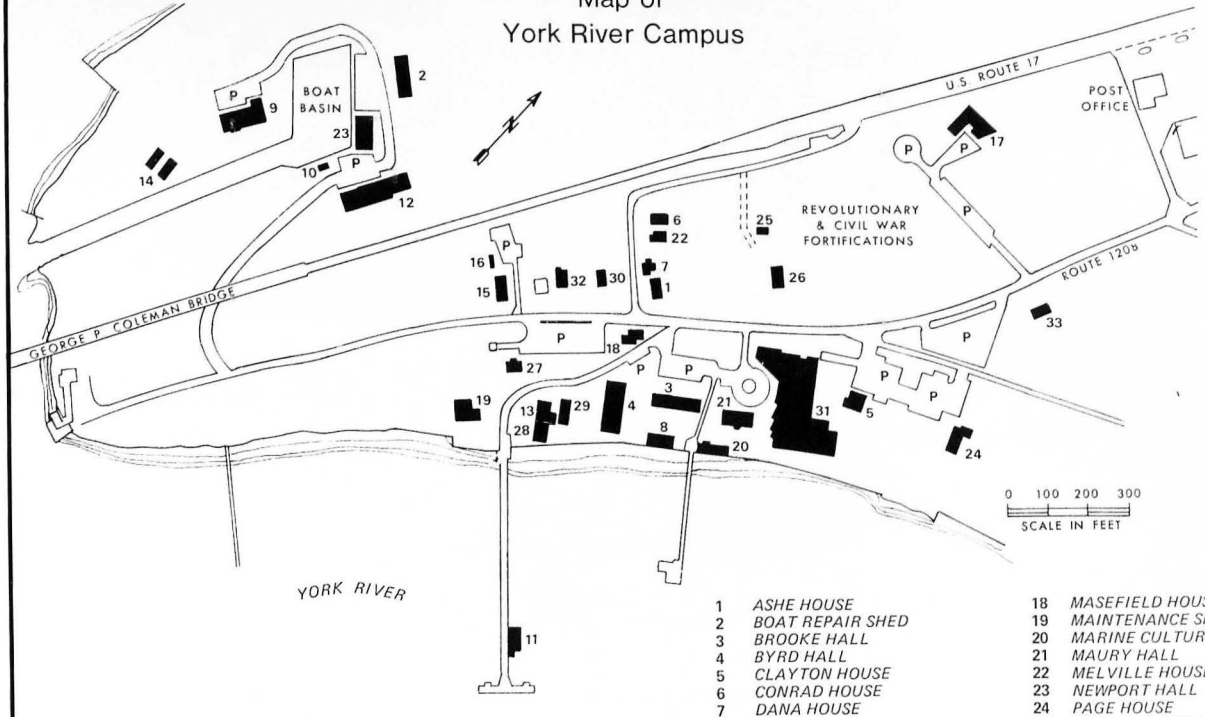
On July 1, 1986, the Institute was reorganized, as outlined below, to achieve a threefold purpose: 1) to provide the Dean/Director a better opportunity to interact with the federal government for the purpose of obtaining increased federal funding thereby enabling the Institute to be more responsive to needs of the managers of Virginia's marine resources; 2) to concentrate the administrative duties with fewer individuals, thereby freeing more faculty to engage in research, education and advisory services; and 3) to encourage and facilitate interdisciplinary research at the Institute by combining within selected divisions appropriate research capabilities which were previously separated.



Editor - Charles M. Holloway
Photo Credits:
William W. Jenkins - cover, ii, 4, 8, 10, 11, 15, 20, 49
Michael J. Oesterling - 57
C. James Gleason - 1
Formal Masters, Inc. - 5
Typesetting - Ruth Hershner, Janet Walker
Graphic Design - Kay Stubblefield



Map of York River Campus



1 ASHE HOUSE	18 MASEFIELD HOUSE
2 BOAT REPAIR SHED	19 MAINTENANCE SHOP
3 BROOKE HALL	20 MARINE CULTURE LAB
4 BYRD HALL	21 MAURY HALL
5 CLAYTON HOUSE	22 MELVILLE HOUSE
6 CONRAD HOUSE	23 NEWPORT HALL
7 DANA HOUSE	24 PAGE HOUSE
8 DAVIS HALL	25 POOL CAR GARAGE
9 DEMONSTRATION BUILDING	26 RALEIGH HOUSE
10 DIVING LOCKER	27 REED HOUSE
11 FERRY PIER HOUSE	28 SALT WATER LAB
12 FRANKLIN HALL	29 SEDIMENT LAB
13 GARAGE	30 STEVENSON HOUSE
14 GREENHOUSES	31 WATERMEN'S HALL
15 HOXTON HALL	32 WHITE HOUSE
16 HOXTON ANNEX	33 WILLIAMS HOUSE
17 JEFFERSON HALL	P PARKING

COLLEGE OF WILLIAM AND MARY
Virginia Institute of Marine Science /
School of Marine Science